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ORIGINAL PAPER

Distribution, contamination, and health risk assessment of heavy metals in surface soils from northern Telangana, India

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Abstract

The aim of the present study was to assess the levels of heavy metal contamination in soils and its effects on human health in the northern Telangana, India. Soil samples were collected randomly from 15 sampling stations located in the northern Telangana and analyzed for arsenic (As), chromium (Cr), copper (Cu), zinc (Zn), nickel (Ni), and lead (Pb). The index of geo-accumulation (I_{geo}), ecological risk index (ERI), hazard quotient (HQ), hazard index (HI), cancer risk (CR), and lifetime cancer risk (LCR) were used to estimate the heavy metal pollution and its consequence to human health. Results indicated that As, Zn, Cu, Pb, and Ni were within recommended limits, while Cr concentration (60 mg/kg) exceeded the maximum recommended limit in 93% of soil samples. The HI values of Cu, Ni, and Zn were all less than the recommended limit of HI = 1, indicating that there were no non-carcinogenic risks from these elements for children and adults. LCR for As and Cr concentrations of the soils was found higher than the acceptable threshold value of 1.0E−04, indicating significant carcinogenic risk due to higher concentration of these metals in the soils of the study region. The chronic daily intake of the metals is of major concern as their cumulative effect could result in several health complications of children and adults in the region. Therefore, necessary precautions should be taken to eradicate the health risk in the study region.

Keywords Soil contamination · Heavy metals · Index of geo-accumulation · Ecological risk index · Heath risk · Northern Telangana

Introduction

Heavy metal contamination in agricultural and urban soils demonstrates both direct and indirect influences on human health via ingestion, dermal contact, and inhalation (Li et al. 2014a). Development of industries, substantial usage of chemicals in agricultural fields, and municipal waste disposals are the principal sources to contaminate the soils in agricultural and urban regions in the world (Luo et al. 2011; Alshahri and El-Taher 2018; Ciarkowska 2018). However, the extreme increase of heavy metals in agricultural and urban soils could be the reason of the soil contamination and also impend to human health. Especially in developing countries, the problem of heavy metal contamination has become much concerned, due to its interrelation with human health (Qing et al. 2015; Li et al. 2014b). Therefore, a number of studies pertaining to contamination of heavy mental in soils have been carried out in all over the world (Li et al. 2015, 2016a; Alshahri and El-Taher 2018). For example, Krishna and Mohan (2016) studied heavy metal contamination in surface soils around an industrial area, India. They found that the arsenic, chromium, copper, nickel, lead, and zinc concentrations were higher than the background values, due to industrial effects in the study region. Ciarkowska (2018) demonstrated that the heavy metal pollution risk of meadow soils in urban area from Poland and found that industrial and anthropogenic sources are the primary of contaminants of the soils. Diami et al. (2016) well studied on ecological risk assessment and human health risks of heavy metals in surface soils in Malaysia and stated that contamination of heavy metals could be the reason for health

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risk in Malaysia. Therefore, significant concern has been attracting much attention in all over the world to soil contamination by toxic elements and impact on human health and environmental quality (Quan et al. 2015; Krishna and Mohan 2016).

The sources of heavy metal in soils and water were predominantly industrial wastes (Sheng et al. 2012; Krishna and Mohan 2016) and anthropogenic contamination (Gu et al. 2016; Chen et al. 2009; Li et al. 2018a, b). Galuskova et al. (2011) found that in the urban areas, the source for heavy metals was mainly from traffic movements. In rural regions, the heavy metal in soils was derived from the agricultural activity (Chen et al. 2009). Luo et al. (2011) reported that irrigation fields were mainly contaminated by copper and cadmium. Gu et al. (2016) conducted extensive study on heavy metals to exposed lawn soils from 28 urban parks in China and found that vehicle emission is the principal reason for contamination of the surface soil by heavy metals. Quan et al. (2015) stated that heavy metal contamination in agricultural surface soils surrounded by e-waste recycling site is very dangerous and polluted soil with nickel, copper, zinc, cadmium, and lead were confirmed by Wong et al. 2007.

The accumulated heavy metals in soil enter into human body by soil ingestion, dermal contact, and inhalation of soil dust (Ciarkowska 2018; Qing et al. 2015; Diami et al. 2016; US EPA 2001; Alshahri and El-Taher 2018; Quan et al. 2015). Soils contaminated by heavy metals could pose very hazardous effects on human health as well as environment. Diami et al. (2016) pointed out that the contamination of heavy metals not only portends the human health but also deteriorates the surface water, groundwater, and quality of atmosphere. Jarup (2003) found that excessive intake of heavy metals lead to diseases related to kidney, blood, cardiovascular, and bone disease. For instance, chronic exposure to Pb and As can lead to adverse effects such as damage the nervous, enzymatic, immune system, kidney dysfunction, dermal lesion, skin cancer, and hypertension (Zhuang et al. 2009; Krishna and Mohan 2016; Diami et al. 2016; Ciarkowska 2018; Qing et al. 2015; Quan et al. 2015). Some other metals, such as cadmium (Cd), chromium (Cr), and copper (Cu), cause anuria, nephritis, and extensive lesions in the kidney (Qing et al. 2015). Consequently, due to their potential toxic, persistent, and irreversible characteristic, the heavy metals, such as Cd, Cr, As, Hg, Pb, Cu, Zn, and Ni, have been listed as priory control pollutants by the United States Environmental Protection Agency (US EPA) and caused more and more attention in many parts of the world (Chen et al. 2015; Rodrigues et al. 2013; US EPA1997, 2001). Particular attention has been paid to the quality of soil contamination and its impact on the human health in all over the world. Adverse health effects due to heavy metal contamination of the soil have been widely reported (Xiao et al. 2013; Krishna and Mohan 2016). Heavy metals in soils could pose long-term environmental and health implications because of their non-biodegradability and persistence (Chen et al. 2017; Zeng et al. 2015; Krishna and Mohan 2016; Xiao et al. 2013). However, geo-accumulation index (I_{geo}) and ecological risk index (ERI) have been quite extensively used to determine the heavy metals in contamination of soils in different regions in the world (Zhuang et al. 2009; Krishna and Mohan 2016; Li et al. 2015; Diami et al. 2016; Ciarkowska 2018; Qing et al. 2015; Alshahri and El-Taher 2018; Galuskova et al. 2011; Jarup 2003; Chen et al. 2009, 2017; Quan et al. 2015). Moreover, average daily exposure dose, hazard quotient (HQ), and hazard index (HI) have widely been used in the worldwide to identify the carcinogenic and non-carcinogenic risk (NCR) of human health, when extensively exposed to heavy metals in soils, which is developed by US EPA (US EPA 1986, 2001, 2005).

Nirmal, is one of the district in Telangana, is experiencing rapid urbanization and industrialization. However, evaluation of heavy metal pollution in soils and its health risk assessment have not been undertaken in this study region. This signifies a knowledge gap for understanding the potential effects of soil heavy metals on human health. Therefore, the study deals with heavy metal contamination in soil and its possible human health risk in the study region. The main objectives of this study were (a) to determine the concentration of six heavy metals [arsenic (As), chromium (Cr), copper (Cu), zinc (Zn), nickel (Ni), and lead (Pb)], (b) to delineate the contamination factors using I_{geo}, and (c) to estimate the potential impact of soil heavy metal contamination on human health of adults and children through different pathways. Hence, the findings are very beneficial for providing pollution prevention measures in soil as well as reducing human health risk in the study region.

Materials and methods

Study area, sampling, and analysis

The study region is situated in the southwestern part of Nirmal Province, located at the northern Telangana, India. It is bounded by 77.99921 to 77.90838 east longitudes and 18.99821 to 18.85043 north latitudes and falls in Survey of India toposheet 56E/13, and geologically, the area is covered by hard rock terrain (Fig. 1). The mean daily minimum and maximum temperature is observed as 15 and 29 °C during December and 28 and 46 °C during May month. Red and black soils are both found in the Nirmal Province, though black soil predominates, accounting for 70% of the soil in the study region (Narsimha and Sudarshan 2017).

A total of 15 surface soils were collected in northern Telangana, India, in clean polythene covers circumventing the all possible contamination. Samples were collected from top 10–50 cm layer of the soil using plastic spatula, and the

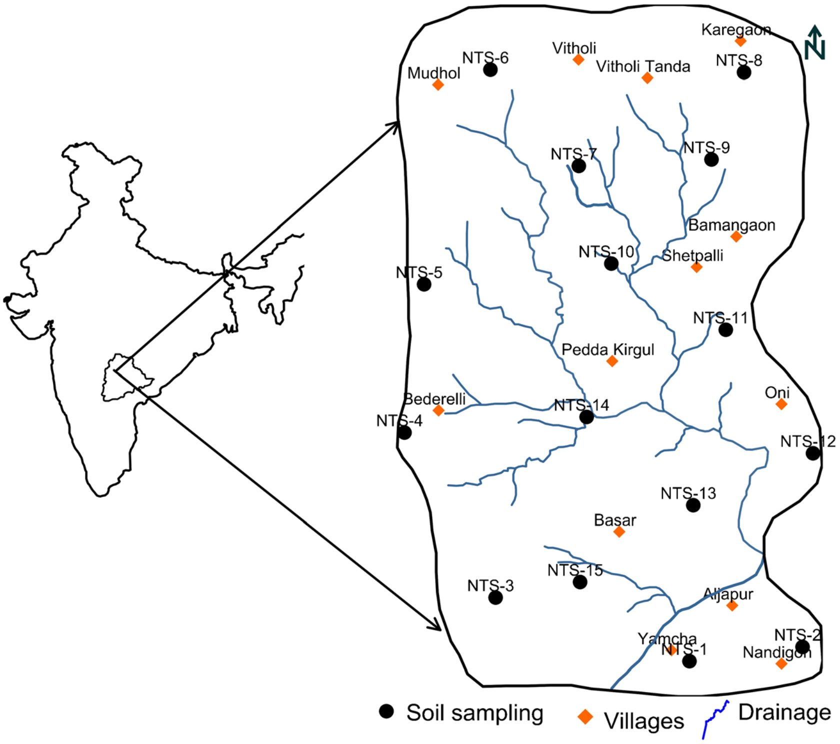

Fig. 1 Location map of soil samplings in the northern Telangana, India

location of each sample was recorded using a global positioning system (Fig. 1). Soil samples were dried for 2 days at 60 °C. The dry soil samples were disaggregated with mortar and pestle. The samples were finely powdered to –250 mesh size (US Standard) using a swing grinding mill. Sample pellets were prepared for analysis of trace and major elements by X-ray fluorescence (XRF) spectrometry using a backing of boric acid in collapsible aluminum cups and pressing at 20 tons of pressure. A hydraulic press was used to prepare the pellets for XRF analysis (Krishna and Mohan 2016; Govil 1985).

A fully automated Philips MagiXPRO-PW2440, microprocessor controlled, 168 position automatic PW 2540 vrc sample changer wavelength dispersive X-ray spectrometer was used along with 4KW X-ray generator for the determination of heavy metals (As, Cr, Cu, Ni, Pb, and Zn) in soil samples. The MagiX PRO is a sequential instrument with a single goniometer-based measuring channel covering the complete elemental range. A rhodium (Rh) anode is used in the X-ray tube, which may be operated up to 125 mA, at a maximum power level of 4 kW. Suitable software "Super Q" was used to take care to dead time correction and inter-element matrix effects (Krishna and Govil 2008; Krishna and Mohan 2016).

Index of geo-accumulation

The index of geo-accumulation (I_{geo}) was introduced in early 1960s into sediment geochemistry to assess the degree of heavy metal contamination in sediments. However, a number of researchers used to evaluate the heavy metal contamination in soils in the world. It is computed by using the following equation (Müller 1969; Li et al. 2016a):

$$I_{geo} = \log_2 \frac{C_{HMS}}{1.5 \times GBV} \quad (1)$$

where C_{HMS} is the concentration of heavy metals in soils, and *GBV* is the geochemical background value. The constant 1.5 allows to analyze natural fluctuations in the content of a given substance in the environment (Müller 1969). According to Müller (1969), the I_{geo} for each metal is calculated and classified as uncontaminated ($I_{geo} \leq 0$); uncontaminated to moderately contaminated ($0 < I_{geo} \leq 1$); moderately contaminated ($1 < I_{geo} \leq 2$); moderately to heavily contaminated ($2 < I_{geo} \leq 3$); heavily contaminated ($3 < I_{geo} \leq 4$); heavily to extremely contaminated ($4 < I_{geo} \leq 5$); and extremely contaminated ($I_{geo} \geq 5$).

Ecological risk index

The potential risk of soil heavy metal pollution was evaluated using the ERI introduced by Hakanson (1980). The ecological risk of heavy metals is classified into five levels according to the values of E_r^i and ERI (Table 1), and computed using following Eqs. (2) to (4):

$$ERI = \sum_{i=1}^{n} E_r^i \quad (2)$$

Table 1 Classification criteria of the ecological risk factor (E_r^i), and ecological risk index (ERI) of heavy metals

E_r^i	Risk classification	ERI	Risk classification	Reference
$E_r^i < 40$	Low risk	ERI < 150	Low risk	Hakanson 1980; Xu et al. 2008
$40 < E_r^i < 80$	Moderate risk	150 < ERI < 300	Moderate risk	
$80 < E_r^i < 160$	Considerable risk	300 < ERI < 600	Considerable risk	
$160 < E_r^i < 320$	High risk	ERI > 600	High risk	
$E_r^i > 320$	Very high risk	/	/	

$$E_r^i = T_r^i \times C_f^i \tag{3}$$

$$C_f^i = \frac{C^i}{C_n^i} \tag{4}$$

where C_f^i is the pollution coefficient of single metal; C^i is the measured concentration of sample; C_n^i is the background concentration of soils; T_r^i is the toxicity factor of different metals; E_r^i is the potential ecological risk factor of single metal; *ERI* is the ERI of six metals. According to the research work of Hakanson 1980 and Xu et al. 2008, the T_r^i values for As, Ni, Cu, Pb, Cr, and Zn are 10, 5, 5, 5, 2, and 1, respectively.

Health risk assessment of heavy metals in soils

Health risk assessment is used to delineate the non-carcinogenic and carcinogenic risks to the human due to chemical exposure (Adimalla et al. 2018; Narsimha and Rajitha 2018; Wu and Sun 2016; Li et al. 2016b, 2017; Adimalla 2018a, b). Normally, humans are exposed to soil metals through three main pathways, such as ingestion, inhalation, and dermal contact. US EPA proposed a fundamental method to estimate the dose received through ingestion, dermal, and inhalation (US EPA 1986, 2001, 2005). The average daily exposure dose (mg/kg/day) of potentially toxic metals via ingestion, dermal contact, and inhalation for both adults and children were computed using Eqs. (5) to (7), respectively.

$$ADD_{\text{ingestion}} = \frac{CMS \times IR \times ED \times EF}{ABW \times AET} \times CF \tag{5}$$

$$ADD_{\text{dermal}} = \frac{CMS \times SA \times SAF \times DAF \times EF \times ED}{ABW \times AET} \times CF \tag{6}$$

$$ADD_{\text{inhalation}} = \frac{CMS \times IHR \times ED \times EF}{ABW \times AET \times PEF} \tag{7}$$

where *ADD* is the average daily dose (mg/kg/day), *CMS* is the concentration of metal in soil (mg/kg), *IR* and *IHR* are the ingestion and inhalation of metal in soil, respectively (mg/day), *ED* is the exposure duration (year), and *EF* is the exposure frequency (day/year). *ABW* and *AET* represent the average body weight (kg) and average exposure time period (year), respectively. *CF* is the conversion factor (10^{-6} kg/mg), *SA* is the exposed skin surface area (cm^2), *SAF* is the skin adherence factor (kg/cm^2 day), *DAF* is the dermal absorption factor, and *PEF* is the particle emission factor (m^3/kg).

The reference dose is used as a measure of non-carcinogenic chronic hazards. Toxic effects are likely to ensue, when the exposure dose of the target contaminant exceeds the reference dose, which is generally articulated as HQ and HI. The estimation of chronic risk level was expressed as HQ computed for a soil heavy metals. The HI is the sum of the HQ and indicates the total risk of non-carcinogenic for a single element (Eqs. (8) and (9)):

$$HQ = \frac{ADD}{RfD} \tag{8}$$

$$HI = \sum\left(HQ_{\text{ingeston}} + HQ_{\text{inhalation}} + HQ_{\text{dermal}}\right) \tag{9}$$

where *RfD* is the reference dose (mg/kg day) adopted from US EPA 1986, 2001. If the value of HI < 1, no significant risk of non-carcinogenic effects is believed to occur. If HI > 1, then there is a possibility of non-carcinogenic effects, and the probability increases with the increasing HI value (US EPA 2001, 2005).

The heavy metals evaluated in the study are arsenic (As), chromium (Cr), copper (Cu), zinc (Zn), nickel (Ni), and lead (Pb). As, Cr, and Pb were classified as carcinogenic risk elements, while Cu, Ni, and Zn were considered as non-carcinogenic (US EPA 2001). The carcinogenic risk or the lifetime cancer risk (LCR) is calculated using Eq. (10), which is the summation of the cancer risk (CR) from each exposure pathway.

$$\text{Cancer risk(CR)} = ADD \times CSF \tag{10}$$

The cancer slope factor (*CSF*) values for Cr, Pb, and As are 0.5, 0.0085, and 1.5 mg/kg/day (US EPA 2001). The acceptable threshold value of the CR is 1.0E−04, while the tolerable LCR for regulatory purposes was ranged from 1.0E−06 to 1.0E−04 (US EPA 2001), which was computed as a sum of CR (ingestion, inhalation, and dermal), shown below:

$$\text{Lifetime cancer risk(LCR)} = \sum \text{CR (ingestion + inhalation + dermal)} \tag{11}$$

The detailed probabilistic parameters like IR, IHR, ABW, AET, ED, EF, SA, AF, ABS, PEF, and RfD values are presented in Table 2.

Results and discussion

The levels of the metals in the soil at various sampling points were summarized in Table 3, while the minimum, maximum, mean, median, standard deviation, coefficients of variations, skewness, and kurtosis in the study area were presented in Table 4. Chromium is a heavy metal whose presence in soil, water, and atmosphere can cause hazard to the natural environment, and it can exist in oxidation levels varying from − 2 to + 6, but in the environment chromium is mainly present in + 3 and + 6 state (Adriano 2001; Kabata-Pendias and Pendias 2001). Cr levels in the soil of the study area ranged from 55.9 to 135.8 mg/kg, with an average of 100.64 mg/kg (Tables 3 and 4). The maximum concentration of 135.8 mg/kg is found in the soil collected near Basara railway station and minimum concentration of 55.9 mg/kg is found in Yamcha village (Fig. 2). However, 93% of soil sampling sites in the study region were exceeding the maximum permissible limit of Cr (60 mg/kg) in soils (CEQG 2002).

Zinc plays a key role in physical growth and development, the functioning of the immune system, reproductive health, sensory function and neurobehavioral development, and plant growth and animals (Hotz and Brown 2004; Krishna and Govil 2005). However, deficiency of Zn is harmful for humans (premature birth and low birth weight), animals, and crops yields. In the study region, soil has a concentration of Zn ranging from 71.3 to 173 mg/kg, with an average of

Table 2 Reference values of some parameters for exposure health risk assessment of heavy metals in surface soils from the northern Telangana, India

Factor	Unit	Adult	Children	Reference
IR	mg/day	100	200	US EPA 2001, 1986
ED	Years	24	6	US EPA 1997
EF	Days/year	365	365	US EPA 2001
CF	kg/mg	1×10^{-6}	1×10^{-6}	US EPA 2001
ABW	kg	70	15	Narsimha and Rajitha 2018
AET	Years	8760	2190	US EPA 2001
SA	cm^2	4350	1600	US EPA 2001
SAF	mg/cm^2	0.7	0.2	US EPA 2011
DAF	/	0.001	0.001	US EPA 2001
IHR	m^3/day	12.8	7.63	US EPA 2001
PEF	m^3/kg	1.36×10^9	1.36×10^9	US EPA 2001
RfD	mg/kg day	Ingestion: As (0.0003), Cr (0.003), Pb (0.0035), Cu (0.04), Ni (0.02), Zn (0.3) Dermal: As (1.23E-04), Cr (6.00E-05), Pb (5.25E-04), Cu (1.20E-02), Ni (5.40E-03), Zn (6.00E-02) Inhalation: As (1.23E-04), Cr (2.86E-05), Pb (3.52E-03), Cu (4.00E-02), Ni (2.06E-02), Zn (3.00E-01)		US EPA 2001, 1997
CMS	mg/kg	As: 2.4 to 5.3; Cr: 55.9 to 135.8 Pb: 5.9 to 26.8; Cu: 12.7 to 69.6 Ni: 0.5 to 27.6; Zn: 71.3 to 173		Current study

IR: ingestion rate of soil
ED: exposure duration
EF: exposure frequency
CF: conversion factor
ABW: average body weight
AET: average exposure time
SA: skin surface area
SAF: skin adherence factor
DAF: dermal absorption factor
IHR: inhalation rate of metal in soil
PEF: particle emission factor
RfD: reference dose
CMS: concentration of metals in soils

Table 3 Soil samples locations and its analysis of Cr, Zn, Cu, Pb, Ni, and As in the study region

Sample ID	Longitude	Latitude	Cr	Zn	Cu	Pb	Ni	As
NTS-1	77° 58′ 11″	18° 51′ 21″	55.9	173	12.7	26.8	10.2	5.3
NTS-2	77° 59′ 38″	18° 51′ 32″	94.8	91.4	26.6	18.3	11.2	3.7
NTS-3	77° 55′ 42″	18° 52′ 10″	135.8	87.9	38.4	24.9	27.6	3.8
NTS-4	77° 54′ 32″	18° 54′ 17″	129.8	88.7	40.2	21.5	26.4	3.7
NTS-5	77° 54′ 47″	18° 56′ 11″	117.9	96.8	40	20.5	24.3	3.7
NTS-6	77° 55′ 38″	18° 58′ 56″	105.9	86.4	45.4	16.8	21	3.2
NTS-7	77° 56′ 46″	18° 57′ 42″	77.9	71.3	14	14.9	10.2	3.1
NTS-8	77° 58′ 53″	18° 58′ 54″	85.9	72.2	14.9	21.6	1.2	3.8
NTS-9	77° 58′ 28″	18° 57′ 47″	87.6	73	17.4	17.1	2.1	3.5
NTS-10	77° 57′ 11″	18° 56′ 27″	83.7	74	15.1	19.9	0.5	3.5
NTS-11	77° 58′ 39″	18° 55′ 36″	87.5	80.5	18.9	11.4	2.3	2.9
NTS-12	77° 59′ 46″	18° 54′ 01″	119.9	99	69.6	5.9	19.3	2.4
NTS-13	77° 58′ 14″	18° 53′ 21″	76.3	113.1	36	18.6	6.2	2.7
NTS-14	77° 56′ 52″	18° 54′ 29″	120.6	88.5	32	16.9	20.4	3.4
NTS-15	77° 56′ 47″	18° 52′ 22″	130.1	90.6	47.1	17.5	23	3.1

92.43 mg/kg (Tables 3 and 4). All collected soil sampling locations were within the permissible limit of 200 mg/kg (Table 4).

Copper (Cu) is an important trace element for the support of good health for human beings but can be unsafe when human are exposed to higher doses. Chronic exposure to Cu dust could result in undesirable conditions, such as nausea, headaches, and diarrhea. Also, eyes, nose, and mouth irritations may occur (ATSDR 2007). The permissible limit of copper in soil is 63 mg/kg (CEQG 2002). The concentration of Cu in soil of the study area ranged from 12.7 to 69.6 mg/kg with a mean of 31.22 mg/kg (Tables 3 and 4). The high concentration of Cu 69.6 mg/kg was found in agriculture field of Oni area; minimum value is found at Karegaon, Shetpalli, and Yamcha villages (Fig. 2). However, Cu is derived from the soil parent material, waste disposal, fertilizer application, and atmospheric deposition, which are the primary important pathways of cupper in to the environment (Gu et al. 2016; Krishna and Govil 2008; Krishna and Mohan 2016; Alshahri and El-Taher 2018). Rattan et al. (2005) reported that the higher concentration of Cu in soils is due to the organic fertilizers that contributed significantly to greater concentration of Cu in the agricultural lands.

Table 4 Descriptive statistics of soil heavy metal concentrations and comparison with Canadian Environmental Quality Guidelines 2002

Unites/ elements	Cr mg/kg	Zn mg/kg	Cu mg/kg	Pb mg/kg	Ni mg/kg	As mg/kg
Minimum	55.9	71.3	12.7	5.9	0.5	2.4
Maximum	135.8	173	69.6	26.8	27.6	5.3
Mean	100.64	92.43	31.22	18.17	13.73	3.45
Median	94.80	88.50	32.00	18.30	11.20	3.50
SD	23.97	25.05	16.23	5.09	9.87	0.66
CV	0.24	0.27	0.52	0.28	0.72	0.19
Skew	−0.09	2.62	0.78	−0.72	−0.03	1.29
Kurt	−1.04	8.22	0.49	1.58	−1.66	3.87
PL	60	200	63	140	50	12
%SWL	100	100	93.4	100	100	100
%SEL	/	/	6.60	/	/	/

SD: standard deviation

CV: coefficients of variation

Skew: skewness

Kurt: kurtosis

PL: permissible limit (Canadian Environmental Quality Guidelines 2002)

%SWL: % of samples within the limits

%SEL: % of samples exceeding the limits

Lead is the second most common contaminant, and also, it is a second on the list of the top 20 hazardous substances by the US Environmental Protection Agency (US EPA) and Agency for toxic substances and disease registry (ATSDR 2007). The normal concentration of Pb in soils is in the range of 10 to 20 mg/kg, and a concentration level of larger than 100 mg/kg indicates perilous for humans (Krishna and Govil 2008; Krishna and Mohan 2016). High intake of Pb leads to metabolic disorders and neuro-physical deficits in children and affects the hematologic and renal system (Gu et al. 2016). Pb interferes with the incorporation of iron into the protoporphyrin leading to anemia and causes renal damage (Kabata-Pendias and Pendias 2001). In the soils of the study region, Pb ranged from 5.9 to 26.8 mg/kg, with a mean of 18.17 mg/kg (Tables 3 and 4). The high concentration of Pb was noticed in the samples NTS-3 and NTS-1, while low concentration was in NTS-12 (Fig. 3).

Nickel is the 23rd common element of earth crust; most of it is derived from igneous rock serpentine (ultrabasic). The major sources of nickel are sewage sludge when applied on

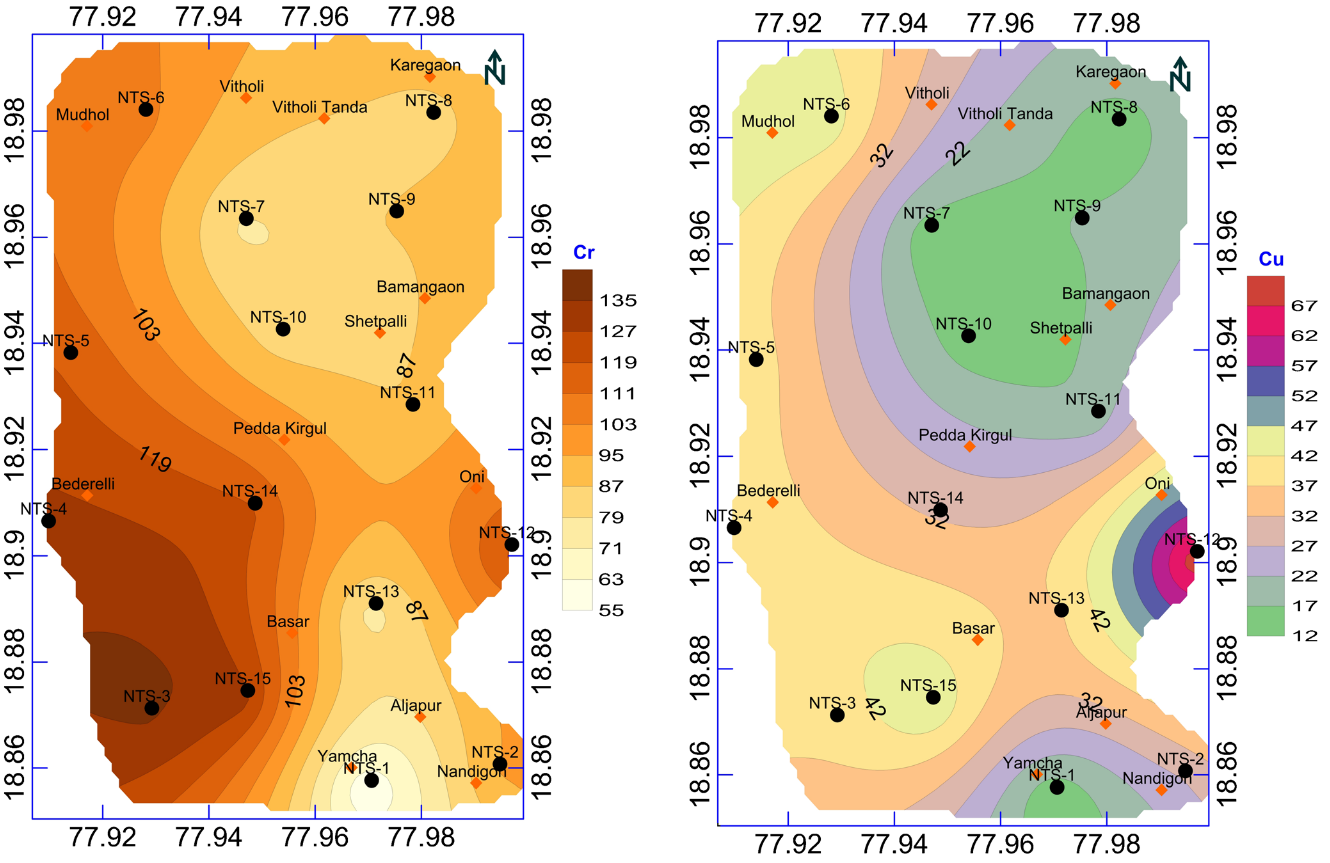

Fig. 2 Spatial distributions of Cr and Cu in the study area

land can cause enrichment of nickel in soils and also application of phosphoric fertilizer in agricultural land (Raju et al. 2011; Aslam et al. 2013; Adriano 2001). Furthermore, it depends on the origin of the soil and pedogenic processes, the surface, or the subsoil, which may be relatively enriched or have the same Ni concentrations. The Ni content of soils in the study region ranged from 0.5 to 27.6 mg/kg, with a mean of 13.73 mg/kg (Tables 3 and 4), which is below the maximum permeable limit of 50 mg/kg (CEQG 2002). However, higher content of Ni and Cr causes for lung cancer (Rattan et al. 2005).

Arsenic occurs naturally in soils as a result of the weathering of the parent rock (Adriano 2001; Kabata-Pendias and Pendias 2001; Aslam et al. 2013). Although it occurs in igneous rocks, the greater concentrations tend to be found in argillaceous sedimentary rocks (e.g., shales and mudstones) and in heavily sulfidic mineralized areas (Olawoyin et al. 2012). Agricultural practice including the historical use of arsenic-based pesticides and ongoing application of fertilizers, sludges, and manures containing arsenic has resulted in the accumulation of arsenic in top soils (Kabata-Pendias and Pendias 2001; Raju et al. 2011; Krishna and Govil 2005). The concentration of As ranged from 2.4 to 5.3 mg/kg, with a mean of 3.45 mg/kg (Tables 3 and 4). The background natural concentration of As in the soils is ~ 5–10 mg/kg; however, its distribution is not homogenous in the Earth's crust and it depends on geologic settings (Ravenscroft et al. 2009; Rodríguez et al. 2008). Conversely, Canadian Environmental Quality Guidelines (CEQG) has set maximum permissible limit of As in soil as 12 mg/kg (CEQG 2002). As concentration in soils is found below the permissible limit in the study area. The higher concentration of As in soil was noticed from the sample number NTS-1 (Yamcha), due to excessive use of agricultural fertilizers and geogenic process which could be the major reasons (Fig. 3). Eventually, the results showed that Cr has the highest mean concentration in the soils, followed by Zn, Cu, Pb, Ni, and As (Table 4).

Spatial distribution of heavy metals

The spatial distributions of heavy metals in soils from northern Telangana were depicted in Figs. 2, 3 and 4. According to Figs. 3 and 4, the As, Pb, and Zn in soils of this study area had similar spatial distributions, with higher concentrations located in the southern part and low concentrations located in the eastern part for As and Pb and northern part for Zn in the study region. Cu spatial distribution in soil shows higher concentration in the eastern part and low concentration located in the north and southern parts of the study region (Fig. 2). Compared with other heavy metals, Ni and Cr in soils showed

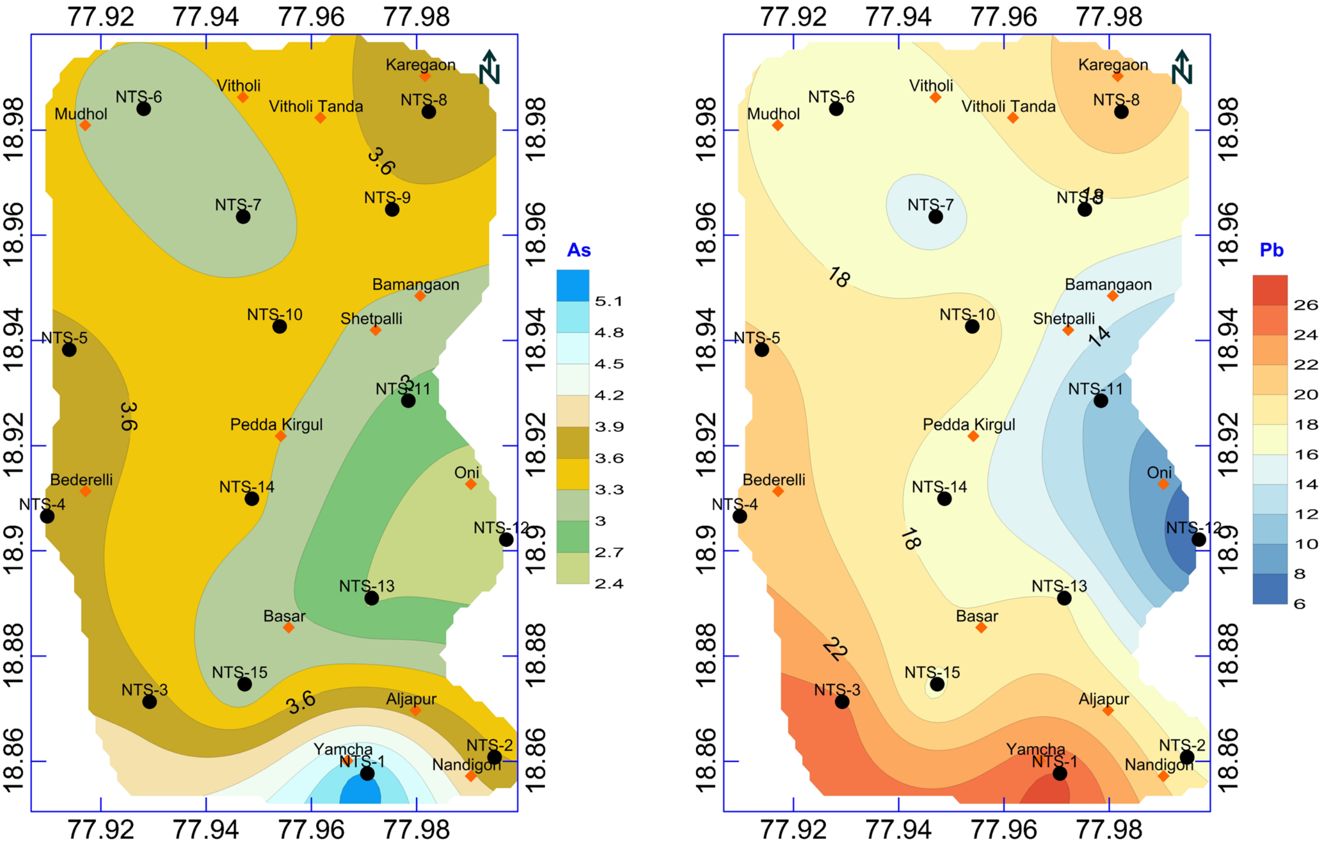

Fig. 3 Spatial distributions of Pb and As in the study area

different spatial distributions, but they were not exceeding the standard values (Figs. 2 and 4). Zeng et al. (2015) found similar distribution pattern in Tianjin sewage irrigation area, due to huge application of fertilizers in the crop land. Rodríguez et al. (2008) reported that a common variation was noticed for Cr, Cu, Ni, Pb, and Zn at a regional scale, whereas at a local scale, Cu, Zn, Pb, and Cd were constituted an anthropogenic component related to human activities and Cr and Ni were associated with parent material. Sun et al. (2013) suggested that the source of Cr, Cu, Ni, Pb, and Zn was due to geochemical processes when studying their distribution at a regional scale; the agricultural practices which influence the concentration of heavy metals in soils were limited to a local scale.

Index of geo-accumulation and ecological risk index

I_{geo} and ERI have extensively been used to evaluate the degree of metal contamination/pollution in soils in all over the world (Alshahri and El-Taher 2018; Pandey et al. 2016; Krishna and Mohan 2016; Luo et al. 2011; Diami et al. 2016; Li et al. 2016a; Mamat et al. 2016). The distribution of I_{geo} values were depicted in Fig. 5a, b. The negative I_{geo} values of As, Ni, and Pb were indicated that there was no contamination in the soils, which were fell in I_{geo} class-I, and these are found in the soil mostly from the natural processes. The I_{geo} for Zn and Cr in the study region soils ranged from − 0.53 to 0.75, and − 0.91 to 0.37 with a mean of − 0.19 and − 0.11, respectively (Supplementary Table 1), with most of the sampling stations smaller than zero, except NTS-1 and NTS-11 for Zn, and NST-3, NST-4, NST-5, NST-6, NST-12, NST-14, and NST-15 for Cr which was larger than zero (Fig. 5a), indicating practically uncontaminated (class-I) and uncontaminated to moderately contaminated (class-II), respectively. However, the I_{geo} of Cu ranged from − 1.42 to 1.04 with a mean − 0.31 (Supplementary Table 1). The I_{geo} of Cu (1.04) is much higher than values of the other elements, falling into the third category of the index (class-III), indicating that the soils are moderately contaminated.

The ERI was widely used to evaluate the potential ecological risk caused by pollutants, such as heavy metals and their impact to an ecological system (Diami et al. 2016; Luo et al. 2011; Mamat et al. 2016). The ERI assessment takes into account the toxicity effect of the metal element alongside the measured concentration of soil in comparison with the reference value of the heavy metal in the Earth's crust (Eqs. (2) to (4)). The detailed results of the potential ecological risk factor (E_r^i) of single elements, and ERI of heavy metals is presented in Table 5. The single ecological risk indices of the soil heavy metals in the study region decreased in the order of Cu > Pb >

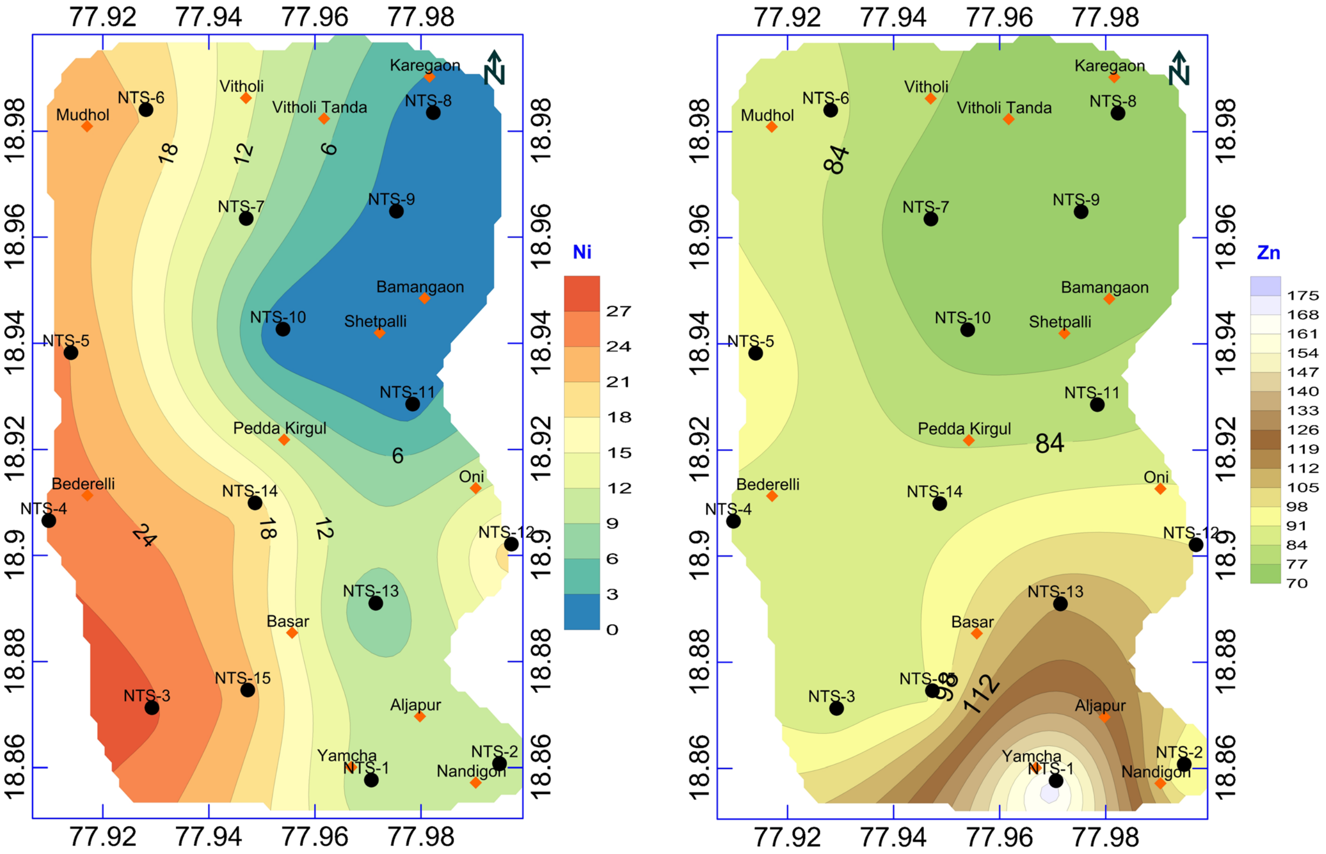

Fig. 4 Spatial distributions of Ni and Zn in the study area

As>Cr > Ni > Zn. However, single ecological risk of Cu in soils ranged from 2.81 to 15.40, with a mean of 6.91, which indicated that Cu was in the low risk and remaining heavy metals (Pb, As, Cr, Ni, and Zn) of E_r^i values with much lower levels, their maximum values were less than seven, which also specifies that all Cu, Pb, As, Cr, Ni, and Zn were in the low risk (Fig. 6). Furthermore, ERI calculated as the sum of the value of single ecological risk factor of heavy metals (Eq. (2)), and ERI classified into four categories, such as low risk, moderate risk, considerable risk, and high risk (Table 5). The

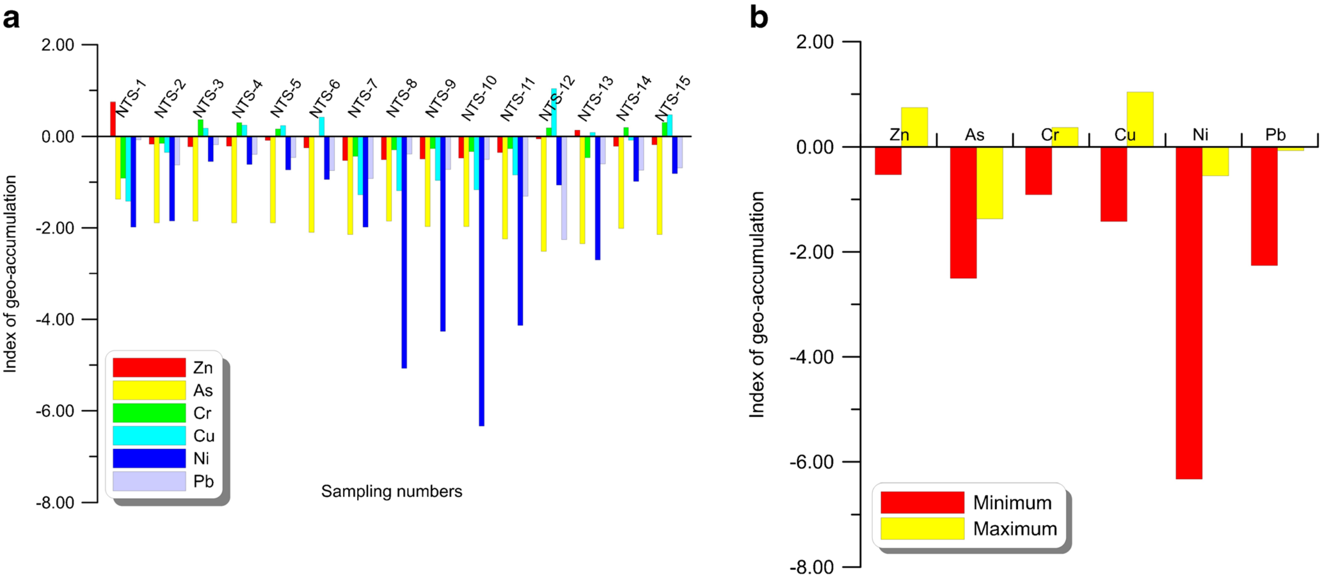

Fig. 5 **a** I_{geo} concentrations. **b** Minimum, maximum of I_{geo} for each metal in soil samples

Table 5 Potential ecological risk factor of single elements, and ecological risk index (ERI) of heavy metals from the study region

Sampling numbers	Potential ecological risk factor						ERI	Risk classification
	Zn	As	Cr	Cu	Ni	Pb		
NTS-1	2.53	5.80	1.59	2.81	1.90	7.13	21.75	Low risk
NTS-2	1.33	4.05	2.70	5.88	2.08	4.87	20.92	Low risk
NTS-3	1.28	4.16	3.87	8.50	5.13	6.62	29.56	Low risk
NTS-4	1.29	4.05	3.70	8.89	4.91	5.72	28.56	Low risk
NTS-5	1.41	4.05	3.36	8.85	4.52	5.45	27.64	Low risk
NTS-6	1.26	3.50	3.02	10.04	3.90	4.47	26.20	Low risk
NTS-7	1.04	3.39	2.22	3.10	1.90	3.96	15.61	Low risk
NTS-8	1.05	4.16	2.45	3.30	0.22	5.74	16.92	Low risk
NTS-9	1.07	3.83	2.50	3.85	0.39	4.55	16.18	Low risk
NTS-10	1.08	3.83	2.38	3.34	0.09	5.29	16.02	Low risk
NTS-11	1.18	3.17	2.49	4.18	0.43	3.03	14.48	Low risk
NTS-12	1.45	2.63	3.42	15.40	3.59	1.57	28.04	Low risk
NTS-13	1.65	2.95	2.17	7.96	1.15	4.95	20.84	Low risk
NTS-14	1.29	3.72	3.44	7.08	3.79	4.49	23.81	Low risk
NTS-15	1.32	3.39	3.71	10.42	4.28	4.65	27.77	Low risk
Minimum	1.04	2.63	1.59	2.81	0.09	1.57	14.48	/
Maximum	2.53	5.80	3.87	15.40	5.13	7.13	29.56	/
Mean	1.35	3.78	2.87	6.91	2.55	4.83	22.29	/

results of ERI ranged in between 14.48 and 29.56, with a mean of 22.29, indicating that six heavy metals of soils of the study area were in low risk category (Table 5). Zhou et al. (2016) studied spatial variation of soil heavy metals in Eastern China and found that ERI was below 90, indicating that heavy metals in soils of Eastern China were in the light ecological risk. Diami et al. (2016) conducted a study on potential ecological and human health risk of heavy metals in surface soils in Malaysia and estimated the ERI ranged between 44 and 128, indicating low ecological risk.

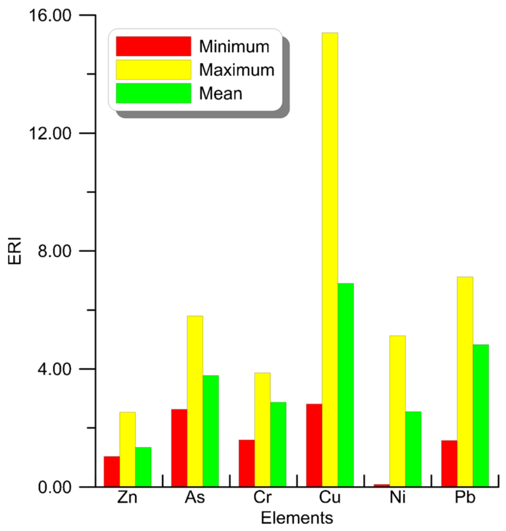

Fig. 6 Minimum, maximum, and mean values of ecological risk index (ERI) of heavy metals in the surface soils of the study region

Human health risk assessment

Non-carcinogenic risk assessment

The NCR results of health risk for heavy metals such as Cu, Ni, and Zn were presented in Table 6. The range of HQ values for children via ingestion for Cu, Ni, and Zn were ranged from 3.15E−03 to 1.34E−02, 2.08E−04 to 6.69E−03, and 7.69E−03 to 7.69E−03, via dermal contact were 9.94E−05 to 2.41E−04, 1.98E−06 to 1.09E−04, and 2.54E−05 to 6.15E−05, and while via inhalation 1.19E−07 to 6.51E−07, 9.08E−09 to 5.01E−07, and 8.89E−08 to 2.16E−07, respectively (Table 6). The HQ values for adults via ingestion for Cu, Ni, and Zn ranged from 4.29E−03 to 8.29E−03, 3.57E−05 to 1.97E−03, and 3.40E−04 to 8.24E−04, via dermal contact were 4.60E−05 to 2.52E−04, 4.03E−06 to 2.22E−04, and 5.17E−05 to 1.25E−04, and while via inhalation 4.27E−08 to 2.34E−07, 3.26E−09 to 1.80E−07, and 3.20E−08 to 7.75E−08, respectively (Table 6). Results indicated that the three different exposure pathways of metals for adults and children decreased in the following order: ingestion > dermal contact > inhalation (Table 6). The contribution of $HQ_{ingestion}$ was higher than HQ_{dermal}, and $HQ_{inhalation}$ of Cu, Ni, and Zn for children and adults in the study region. Similar results were found in Northeast China (Qing et al. 2015). The ratio of the average daily dose to the reference dose can be used to estimate the non-CR to humans: when HQ < 1.00E+00, there are no adverse health effects and HQ > 1, indicating that there are likely adverse health effects (US EPA 1986). However, in the

Table 6 Non-carcinogenic risk via ingestion, dermal, and inhalation exposure pathways for adult and children

		Adults				Children			
		HQ-ingestion	HQ-dermal	HQ-inhalation	HI	HQ-ingestion	HQ-dermal	HQ-inhalation	HI
Cu	Minimum	4.29E−03	4.60E−05	4.27E−08	4.33E−03	3.15E−03	9.94E−05	1.19E−07	3.29E−03
	Maximum	8.29E−03	2.52E−04	2.34E−07	8.46E−03	1.34E−02	2.41E−04	6.51E−07	1.36E−02
	Mean	6.29E−03	1.13E−04	1.05E−07	6.40E−03	7.21E−03	1.79E−04	2.92E−07	7.39E−03
Ni	Minimum	3.57E−05	4.03E−06	3.26E−09	3.97E−05	2.08E−04	1.98E−06	9.08E−09	2.10E−04
	Maximum	1.97E−03	2.22E−04	1.80E−07	2.19E−03	1.62E−02	1.09E−04	5.01E−07	1.63E−02
	Mean	9.80E−04	1.11E−04	8.96E−08	1.09E−03	6.69E−03	5.42E−05	2.49E−07	6.75E−03
Zn	Minimum	3.40E−04	5.17E−05	3.20E−08	3.91E−04	2.06E−03	2.54E−05	8.89E−08	2.08E−03
	Max	8.24E−04	1.25E−04	7.75E−08	9.49E−04	7.69E−03	6.15E−05	2.16E−07	7.75E−03
	Mean	4.40E−04	6.70E−05	4.14E−08	5.07E−04	2.99E−03	3.29E−05	1.15E−07	3.02E−03

HQ: hazard quotient

HI: hazard index

study the $HQ_{ingestion}$, HQ_{dermal}, and $HQ_{inhalation}$ values of three (Cu, Ni, and Zn), heavy metals were all lower than 1.00E+00, indicating that there is no NCR for adults and children.

The HI is the sum of the HQ and indicates that the total risk of non-carcinogenic for a single element was presented in Table 6. The HI value for Cu ranged from 3.25E−03 to 1.36E−02 for children and 4.33E−03 to 8.46E−03 for adults, respectively (Table 6). The HI value for Ni and Zn ranged from 2.10E−04 to 1.63E−02, 2.08E−02 to 7.75E−03 for children, and 3.97E−05 to 2.19E−03 and 3.91E−04 to 9.49E−04 for adults, respectively (Table 6). However, the HI values for the studied elements were all less than the recommended limit of HI = 1, indicating that there were no NCRs from these elements for children and adults. In terms of the two population groups, the NCRs for children were nearly one order of higher degree than the risks for adult, indicating that children encountered more potential harmful health risk through the heavy metals from the study region (Fig. 7a). Similar kinds of results were found in different regions, such as: Tepanosyan et al. 2017 conducted a study on Yerevan's kindergarten's soils heavy metal pollution levels and children health risk assessment, and found children were high scope to effect from

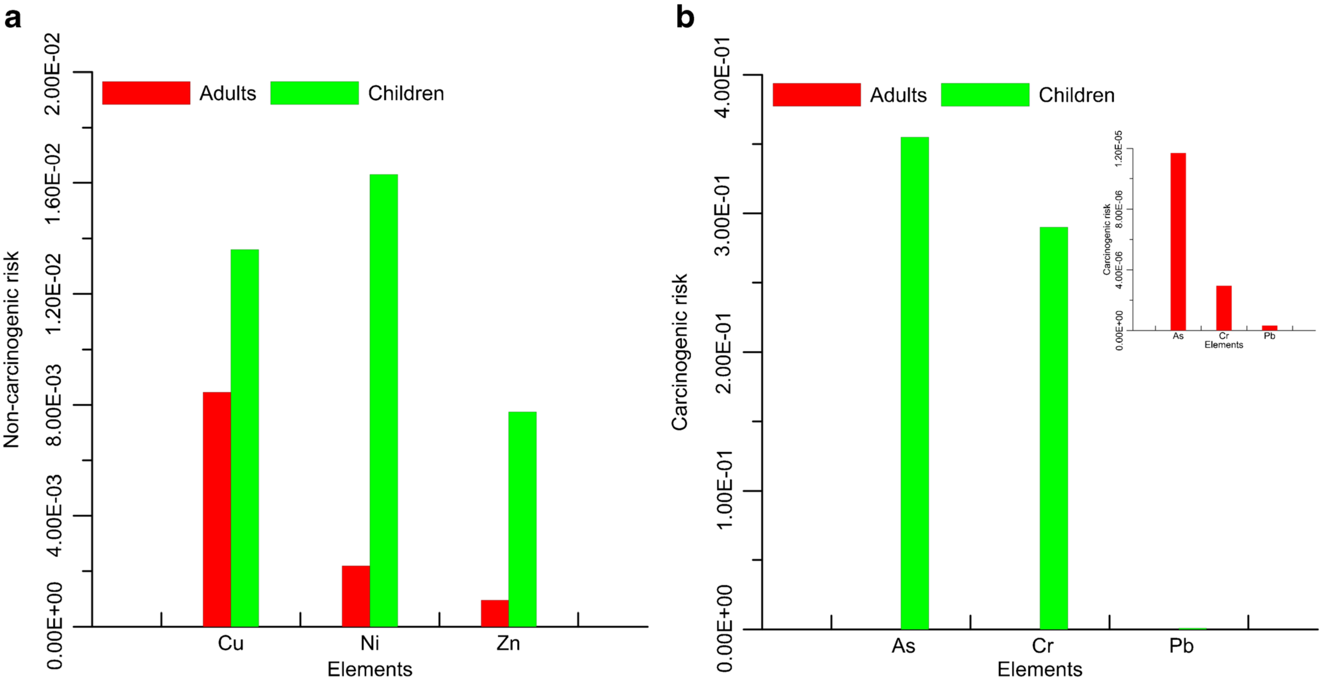

Fig. 7 **a** Non-carcinogenic risk, **b** carcinogenic risk for adults and children in the study area

NCRs. Zhaoyong et al. 2018 also studied on heavy metals in soil from northwest China and found that ingestion was the principal exposure pathway for NCRs of heavy metals in soils, followed by dermal and inhalation. Moreover, in children, these three exposure pathway values were higher than the adults. Most recently, Stevanović et al. 2018 carried out a study on heavy metals in soil of Toplica region, South Serbia and found exposure pathways of metals for children and adults increased in order: inhalation < dermal contact < ingestion. Furthermore, they have specified that the children and adults proposing that ingestion was main exposure pathway for non-carcinogenic health risk. Diami et al. 2016 also found higher HI among children than adults, indicating that children are more susceptible to non-carcinogenic health risks.

Cancer risk assessment

The carcinogenic risks associated with As, Cr, and Pb were evaluated, and the results were presented in Table 7. It was found that the $CR_{ingestion}$, CR_{dermal}, and $CR_{inhalation}$ for As for children ranged from 5.14E−06 to 1.14E−05, 1.57E−07 to 3.46E−07, 4.84E−10 to 1.07E−09 and while adults ranged 9.23E−02 to 3.53E−01, 6.24E−04 to 1.38E−03, and 1.35E−09 to 2.97E−09, respectively (Table 7). The mean value of $CR_{ingestion}$, CR_{dermal}, and $CR_{inhalation}$ for Cr and Pb are 7.19E−05, 2.19E−06, and 6.77E−09, 2.21E−07, 6.72E−09, and 2.08E−011, respectively (Table 7). However, the LCR of As, Cr, and Pb values ranged from 9.29E−02 to 3.55E−01, 1.04E−01 to 2.90E−01, and 1.13E−04 to 8.80E−04 for children, respectively (Table 7). For As and Cr values, LCR was higher than the acceptable threshold value of 1.0E−04 (US EPA 2001), indicating significant carcinogenic risk due to these metal elements in the study region soils. Furthermore, LCR for all heavy metals was found far below the acceptable limits for adults, which reveals that the adults have no carcinogenic risk due to the heavy metals As, Cr, and Pb in the study region (Fig. 7b). However, it was noticed that the As has slightly higher values than the other heavy metals in the study region soils, which specifies that the greater chance to effect the public health of the population living in the study region. Particularly, children were found to be more vulnerable to the potential carcinogenic health risk due to the presence of the heavy metals in the study region. Krishna and Mohan 2016 also found higher carcinogenic risk in children than adults in surface soils around an industrial area, India. Similar results were observed in many other region in the world (Karim and Qureshi 2014; Narsimha and Rajitha 2018; Adimalla et al. 2018; Diami et al. 2016; Stevanović et al. 2018; Zhaoyong et al. 2018). Rapant et al. 2011 noticed that the increased health risk levels in terms of carcinogenic and non-carcinogenic are found basically in every area, where increased soil contamination occurred. Pan et al. 2016 observed that the total carcinogenic risks of As and Cr were higher than the acceptable limit of 1.0E−04 in the soils from a typical county in Shanxi Province, China, where children could be suffered potential carcinogenic risks via ingestion, dermal, and inhalation pathways.

Conclusions

The accumulation of heavy metals in the soils of urban and rural areas can have a negative impact on human health and environment. Therefore, heavy metal contents (As, Cr, Pb, Cu, Ni, and Zn) in soils from the study region were investigated, with an aim of the soil contamination factors and its possible effects on human health risks. A risk assessment adopted from the US EPA was used to calculate the non-

Table 7 Carcinogenic risk via ingestion, dermal, and inhalation exposure pathways for adult and children

Metals		Adults				Children			
		CR-ingestion	CR-Dermal	CR-Inhalation	LCR	CR-Ingestion	CR-Dermal	CR-Inhalation	LCR
AS	Minimum	5.14E−06	1.57E−07	4.84E−10	5.30E−06	9.23E−02	6.24E−04	1.35E−09	9.29E−02
	Maximum	1.14E−05	3.46E−07	1.07E−09	1.17E−05	3.53E−01	1.38E−03	2.97E−09	3.55E−01
	Mean	7.40E−06	2.25E−07	6.96E−10	7.63E−06	1.68E−01	8.98E−04	1.94E−09	1.69E−01
Cr	Minimum	3.99E−05	1.22E−06	3.76E−09	4.11E−05	9.42E−02	9.94E−03	1.05E−08	1.04E−01
	Maximum	9.70E−05	2.95E−06	9.13E−09	1.00E−04	2.66E−01	2.41E−02	2.54E−08	2.90E−01
	Mean	7.19E−05	2.19E−06	6.77E−09	7.41E−05	1.58E−01	1.79E−02	1.88E−08	1.76E−01
Pb	Minimum	7.16E−08	2.18E−09	6.74E−12	7.38E−08	1.10E−04	2.04E−06	6.27E−07	1.13E−04
	Maximum	3.25E−07	9.91E−09	3.06E−11	3.35E−07	8.68E−04	9.26E−06	2.85E−06	8.80E−04
	Mean	2.21E−07	6.72E−09	2.08E−11	2.27E−07	4.32E−04	6.28E−06	1.93E−06	4.41E−04

CR: cancer risk

LCR: lifetime cancer risk

carcinogenic and carcinogenic risks due to life time exposure through three pathways: ingestion of soils, inhalation of soil particulate materials, and soil dermal contact. The following conclusions were met from the study region:

- The concentration of Cr in soils ranged from 55.9 to 135.8 mg/kg, with an average of 100.64 mg/kg. Ninety-three percent of soil sampling sites in the study region were exceeding the maximum permissible limit of 60 mg/kg for Cr in soils (CEQG 2002). Zn concentration ranged from 71.3 to 173 mg/kg. Cu in soil of the study area, ranged from 12.7 to 69.6 mg/kg with a mean of 31.22 mg/kg. Pb, Ni, and As were with guideline value suggested by CEQG 2002.
- I_{geo} values of As, Ni, Cr, Zn, and Pb were negative to larger than zero, indicating practically uncontaminated (class-I) and uncontaminated to moderately contaminated (class-II). The I_{geo} of Cu ranged from − 1.42 to 1.04, indicating moderate contamination. As per ERI, the heavy metals in the soils were shown as low risk category.
- The individual heavy metals do not show significant health risk, but their combined effects are of particular concern. The HI of Cu, Ni, and Zn were all less than the recommended limit, indicating that there were no NCRs from these elements for children and adults. Furthermore, LCR for all heavy metals was found far below the acceptable limits for adults, which reveals that the adults have no carcinogenic risk, but children as the most vulnerable in the population, and also, there are potential LCR posed on children in the northern Telangana.

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