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Quantitative analysis of Physico-Chemical and Heavy Metal Concentration in the Soil of Indian Himalayan Region

Gagan Sharma*, Amandeep Singh and Sheffaly Singla
Department of Biosciences, Central University of Punjab, Bathinda, Punjab (India)
*Email: gagansharmacup@gmail.com, rgsuccess.sharma804@gmail.com

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Abstract

Present study has been undertaken to assess the quantitative level of heavy metal concentrations and their correlation with physico-chemical characteristics in the Himalayan soil. For this, random sampling method was adopted and soil samples from 50 different locations of Indian Himalayan region were collected. All the samples were analyzed for the quantitative analysis of physico-chemical characteristics such as pH, Electrical Conductivity (EC), Water Holding Capacity (WHC) and 7 heavy metals namely Chromium (Cr), Copper (Cu), Iron (Fe), Manganese (Mn), Arsenic (As), Mercury (Hg), and Cobalt (Co) concentrations in (ppm) were measured by AAS (Shimadzu model no. 7000). After analyzing, physico-chemical parameters, the mean values were found to be 5.5 for pH showing acidic nature of the Himalayan soil, 1.129dS/m for Electrical Conductivity (EC) and 43.12% for Water Holding Capacity (WHC). The AAS results depicted the elevated levels of Iron (Fe), Manganese (Mn) and Mercury (Hg), while others such as Copper (Cu), Arsenic (As), Chromium (Cr) and Cobalt (Co) were within the permissible standards of WHO and US-EPA, which indicates the alarming signal of soil pollution for the ecosystem of this region. This work will prove valuable for providing baseline information for further soil quality, monitoring and assessment of heavy metal concentration and their correlation with physico-chemical characters in the study.

Introduction

Environmental pollution from hazardous metals and minerals can arise from natural as well as anthropogenic sources is a global alarming threat of increasing severity due to rapidly increasing industrialization, urbanization, and globalization (Liu *et al.*, 2014). Land deprivation and soil pollution are taking place in the world due to soil erosion, deforestation, urbanization, and industrialization (Birkeland & Noller, 2000; de

Souza *et al*., 2013; Zhao *et al*., 1997, 2013; Varun *et al*., 2011; Takáč *et al*., 2009). Much research has been conducted on heavy metal contamination in soil from various anthropogenic sources such as industrial wastes (Casarett *et al., 2013*; Gibson and Farmer, 1983), pollution by automobile emissions (Garcia-Miragaya., 1984), impact of mining activity on soil (Davies and Ginnever, 1979; Sanyal *et al*., 1982) and wastes produce via agricultural practices (Tindwa *et al*., 2014). Soil establishes the upper layer of the earth, which is composed of minerals and differs from the material of origin in the various aspects such as texture, structure, color, physical, chemical, biological characteristics from place to place (Birkeland and Noller, 2000). The Himalayan soil profile is diversified on the basis of altitude, vegetation, temperature, moisture, slope, and structure (Chandra, et al., 2013). Mostly acidic soils are the characteristic feature of the high altitude of the Himalayan region (Augeri, D; 2018). Heavy metals are natural constituents of the Earth's crust because they cannot be degraded or destroyed and persistent in all parts of the environment and in trace amount they are essential, but their elevated level causing harmful impact on living organisms via entering into the food chain (Wuana and Okieimen., 2011; Wani *et al*., 2011).

Heavy metals enter into the environment via industrial, agricultural, household wastes, mining process of natural resources and atmospheric deposits such as weathering, leaching, etc. (Yadav *et al*., 2009; Tüzen, M., 2003 and Subki *et al*., 2013). They tend to accumulate in the soil, air, water and sediments (Schröder, *et al*., 1994 and Santos, *et al*., 2005), while its contamination in soil is a far more serious problem than air or water pollution because heavy metals are usually tightly bound by the organic components in the surface layers of the soil (Paterson *et al.,* 1996 and Osei *et al*., 2010), consequently, the soil is an important geochemical sink which accumulates heavy metals rapidly and reduces them very slowly by percolating into groundwater or bioaccumulating into plants (Infotox, 2000, and Michalec, B., 2012). Mainly the heavy metal accumulates in the upper layer of soil and become a main causes to change their physico-chemical characteristics such as pH, EC (Electrical Conductivity) and WHC (Water Holding Capacity), etc. (Chatterjee, *et al*., 2006 and Deb *et al*., 2014). Some heavy metals in trace amount are essential for flora and fauna, while their elevated level pose very serious problem same as when macro and micronutrient exceed from their limit via entering into food chain and limits the growth of plant, animals as well as microorganism via incorporate into their structure and causes serious types of problems (Favas, 2016; Gupta and Gupta., 1998 and Israr *et al*., 2006).

The Indian Himalayan Region (IHR) has comprises a rich variety of flora and fauna, while due to the rapid exploitation, habitat destruction, chemical pollution and invasion of alien species, many species have been disappeared. (Chandra and Rao, 2007; Chandra *et al*., 2009; 2010) The vegetation found at an altitude range of 900 m- 5,000 m are Rhododendrons, alpine meadows, Conifers like fir, maple, cedar, deodar, poplar, spruce, walnut, etc.(Khan *et al*., 2013). The density of vegetation in this region is found with various trace elements like heavy metals contribute as a major environmental pollutant and possess a significant impact on its ecological quality (Behera *et al*., 2002). For the monitoring of environmental pollution in this region, it becomes important to analyze the heavy metal concentration and physico-chemical characters of the soil (Zhou *et al*., 1997). Monitoring involves the estimation of metal concentration in soil by comparing with the permissible concentration limits as proposed by the WHO and the US- EPA (Shastre *et al*., 2002). Soil with the high range of heavy metals than permissible limits, can directly or indirectly influence the ecology (Moore and Ramamoorthy, 1984), density of flora and fauna (Melaku *et al.,* 2005) and also the concentrations of macro and micronutrient elements required especially in case of plants (Levy, 2000). Nearly all anthropogenic activities produce waste, and the approach in which this is handled, stored, collected and disposed of, can pose threats to the environment and to public health (Zhu *et al*., 2008). All these anthropogenic activities with some natural factors are mostly responsible for the contamination and pollution of soil in Himalayan region (Khandekar *et al*., 2012). The Physico-Chemical characters have been reported reflective influence on the mobility and bioavailability of heavy metals into flora and fauna in the ecosystem (Tukura *et al*., 2007).

Keeping all these things in mind, the present study was planned to monitoring and analysis of physico-chemical characters and their correlation with the quantitative level or concentrations of selected 7 heavy metals such as Chromium (Cr), Copper (Cu), Iron (Fe), Manganese (Mn), Arsenic (As), Mercury (Hg), and Cobalt (Co) in the soil samples collected from 50 different locations of Western and Eastern Himalayan regions. The determination of the heavy metal content in soil is particularly useful for the purpose of information for the genesis of soil and for assessing the level of contamination also (Xu *et al*., 2004). These toxic elements are considered as soil pollutants and caused acute and chronic toxic effect (Hol *et al*., 1997 and Nagajyoti *et al*., 2010) on the flora and fauna of Himalayan region (Paul., 2013; Chauhan and Lal, 2017 and Singh, D., 2017).

Materials and Methods

Study Area

The study area covers the 50 different locations (Fig-1) of Western and Eastern Himalayan region in India (Table-1). The sampling sites are present at the altitude of 956-4863m (Table 2 and 3) above the sea-level, which are found to be mostly pre-dominated by *Rhododendron, Alpine* and *Conifers* like vegetation. Sampling was done via random sampling method and by digging soil to the depth of 20–25 cm (15×15×25 cm^3 approximately) and 500gm of soil samples from each site were brought to laboratory for further analysis. The soil samples were taken to observe and assess the physico-chemical and quantitative analysis of selected heavy metals. For the physico-chemical analysis, the soil solution was prepared by suspending soil in distilled water in ratio of 1:5 (w/v) and was shaken on the mechanical shaker at room temperature for 5-6 hours. The Physico-Chemical properties of soil samples were determined by following the standard protocols given by Trivedi *et al.*, 1985 and Panwar, 2009 with slight modifications. pH and EC were measured by pH meter (Mettler Teledo, AG).

Heavy Metal Concentration detection techniques

Reagents and Chemicals: In the present study, AR grade chemicals and reagents manufactured by SDFCL and Loba Chemie were used for various chemical analysis and preparation of standard solutions for Atomic Absorption Spectroscopy (AAS) analysis. Standard stock solutions of heavy metals namely Cr, Cu, Fe, Mn, As, Mg, and Co were made at the 1000 ug/mL concentration. 1 gm of soil sample (50 samples) of each location was added in 20 ml of 1:2 (v/v) mixtures of nitric acid and Perchloric acid (Aqua Regia) from AR grade, SDFCL and mixed in ultrapure water by Milli-Q system from Millipore (USA). The mixture was digested to dryness on a hot plate until the appearance of white fumes. Adding 25 ml double distilled ultrapure water and filtered through Whatman filter paper No. 1 and the residue content was washed repeatedly with double distilled water cooled the solution. Working solution of Cr, Cu, Fe, Mn, As, Mg, and Co were calibrated and diluted up to 50ug/mL in volumetric flasks. The determination of metals concentrations (ppm) was performed and analyzed by using Atomic Absorption Spectrophotometer (AAS) (Shimadzu model no. 7000) obtained in triplicate and data was converted into mg/Kg.

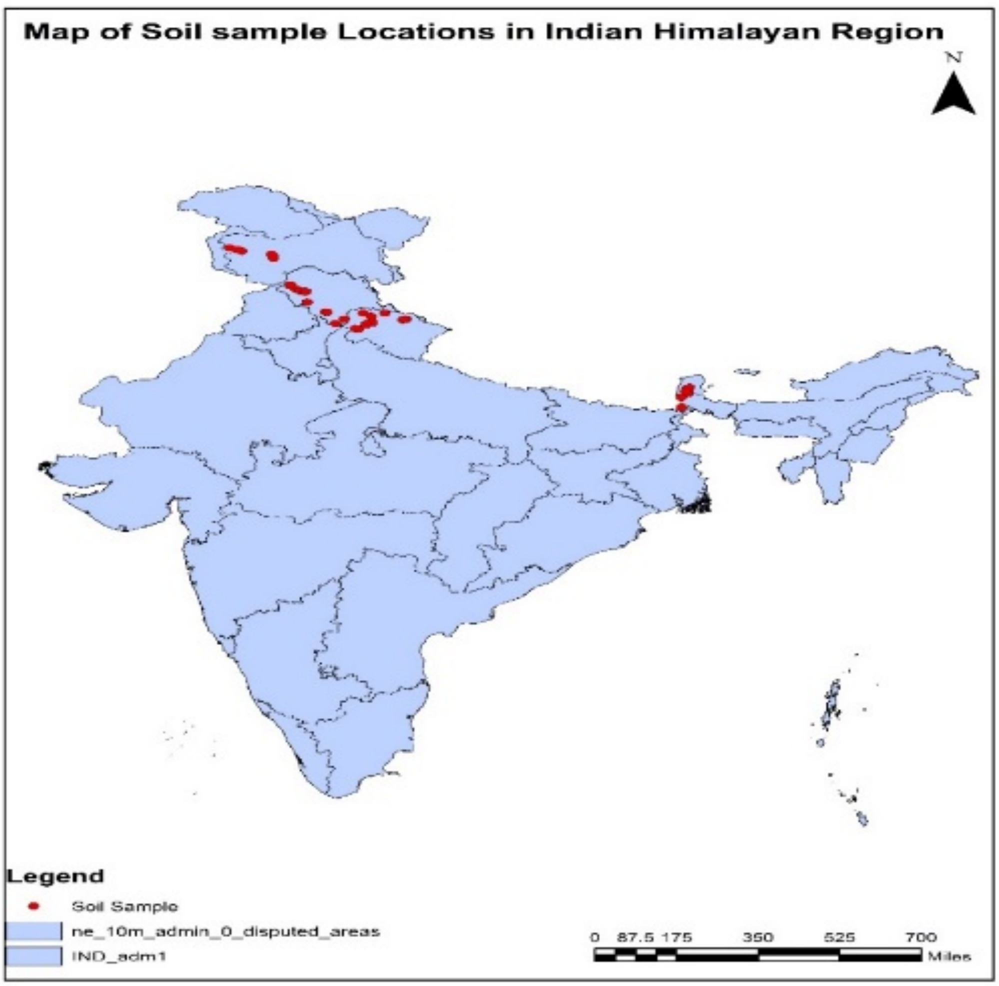

Figure1: Represent the 50 different sampling locations from Indian Himalayan Region

Physico-Chemical Analysis

Determination of Water Holding Capacity (WHC) in (%) of soil samples (Panwar, 2009**)** 10gm of soil sample was taken in Petri plates and put in an oven at 105°C for 24 hours. After 24 hours, soil samples were weighed and transferred in 50 ml beaker and water was poured into the beaker up to its half height. Then the beaker was left overnight. On the next day, excess water was drained off with the help of filter paper and wet soil was weighed on the weighing balance. Water Holding Capacity was determined by dividing the oven dried weight of soil by volume of dried weight. Water Holding Capacity is represented in percentage (%).

$$\textbf{Water Holding Capacity}\ (\%) \quad = \frac{\text{wet weight of soil (g)} - \text{dry weight of soil(g)}}{\text{dry weight of soil (g)}} \times 100$$

Determination of pH and EC of soil samples: Suspension of 10 gm of the soil sample in 25 ml of double distilled water was taken in a 50 ml beaker covered by watch glass and stirred for 1 hour on a magnetic stirrer. The suspension was allowed to settle for 10 minutes and pH of the suspension was taken by using a calibrated pH meter (Trivedi et al., 1985; and Panwar, 2009). EC of the suspension was determined by using a calibrated EC meter. The numerical data produced by AAS and using IBM SPSS statistic software version 1.0 used Physico-Chemical results for the statistical analysis such as Average, Range and correlation.

Results

In the present study, 50 soil samples of different locations from Jammu & Kashmir, Himachal Pradesh, Uttarakhand of Western Himalayan region and Sikkim, Darjeeling (West Bengal) of Eastern Himalayan region were studied for various physico-chemical parameters and monitoring of heavy metal concentration such as Arsenic, Copper, Chromium, Cobalt, Mercury, Iron and Manganese (table 2).

The overall mean pH across all the soil samples shows acidic nature of soil i.e 5.5 in the Himalayan region. Soil samples of KM and SD are slightly acidic, MT, ST, and KD are strongly acidic while TM and GC are moderately acidic but soil sample of GT is slightly alkaline pH. The order of acidity in sampling region are as Jammu & Kashmir >Uttarakhand > Himachal Pradesh > Sikkim and West Bengal. Mainly at the lower elevation, the pH value is slightly acidic or alkaline while at maximum elevation the pH value is strongly acidic (Table 2). These soluble salts are most commonly detected by measuring the soil solution's ability to conduct an electrical current, referred to as electrical conductivity (EC) and its measuring unit is decisiemens per meter (dS/m). The Mean Electrical Conductivity of all the soil samples is 1.219dS/m which demonstrates the non-saline character of the soil. It is found that EC of all the samples is in the non-saline range of soil is less than 2 and the trend is shown as Himachal Pradesh >Uttarakhand > Jammu and Kashmir > Sikkim and Darjeeling (West Bengal).

Table -1: Represent the sampling locations in the Himalayan region

S.N.	Location	Code	Latitude (*DD) N*	Longitude (*DD) E*
1	Margan Top	MT	33°.72419	75°.4772
2	Sinthan Top	ST	33°.59635	75°.49908
3	Toosmaidan	TM	33°.9398	74°.51364
4	Kandi	KD	34°.09214	74°.13087
5	Gaihad Chittergull	GC	33°.78497	75°.43761
6	Khilanmarg(Baramulla)	KM	34°.01825	74°.36218
7	Dhanaulti ,Uttarakhand	DT	30°.2418	78°.14
8	Yamunotri Uttarakhand	YT	30°.99879	78°.954563
9	Barkot , Uttarakhand	BT	30°.86252	78°.524045
10	Chakrata Uttarakhand	CT	30°.72101	77°.695062
11	JankiChatti, Uttarkashi	JC	30°.71632	79°.613487
12	Hanumanchatti, Uttarkashi	HC	30°.69231	79°.514927
13	Badhkot-Yamunotri, Tracking route, Uttarkashi	BY	30°.45293	78°.362947
14	Mussoorie,Uttarkashi	MS	30°.27356	78°.035903
15	Gangtok WSK	GT	27°.20581	88°.37342
16	Bulbulay, NH-310, WSK	BB	27°.20578	88°.37318
17	Sikkim Himalayan Zoological Park, WSK	HZ	27°.20532	88°.37308
18	Varsey Hilay Forest, Sikkim	VH	27°.20703	88°.37308
19	Gyalshing WSK	GS	27°.20965	88°.37587
20	Sanga Choeling, WSK	SC	27°.20538	88°.37282
21	Nathula NSK	N	27°.02984	88°.15953
22	Lachung NSK	LG	27°.02961	88°.15904
23	Lachen NSK	L	27°.4301	88°.332786
24	Mangan NSK	MG	27°.29523	88°.3352
25	Yumthang Valley NSK	YS	27°.49364	88°.414491
26	Rhododendron Wildlife Sanctuary, Lachung	RW	27°.34194	88°.37556
27	Central Bazar, Darjeeling, WB	DB	27°.02318	88°.17547
28	Kurseong Darjeeling	SD	26°.52401	88°.163825
29	Sonada Darjeeling	TS	26°.57358	88°.164861
30	Teesta Tracking Route	YS	27°.3158	88°.3043
31	Gangtori	GT	30°.594	78°.5623
32	Ganganani	G	30°.533	78°.554
33	Lahorinag	L	30°.4905	78°.3705
34	Khajjar-jot	KJ	32°.332	76°.0356
35	Bada gaon	BG	32°.0232	76°.5027
36	Boching	BB	32°0227	76°.5024
37	Yamontri -gang	YG	31°.005	78°.2736
38	Sirmour	SM	30°.512	77°.4203
39	Del-Bakrota Forest	DB	32°.3146	76°.0017
40	Delhousie Khajjar track	BF	32°.3203	76°.00
41	Dharamshala	DS	32°.1433	76°.1916
42	Multhan	M	32°.0244	76°.5033
43	Jot	J	32°.2912	76°.0333
44	Shimla	S	31°.0617	77°.1024
45	Kufri	K	31°.0552	77°.1604
46	Beedh-billing	BD	32°.0244	76°.4324
47	Ghatasani	GH	31°.5245	76°.5452
48	Verni mata	VM	32°.0639	76°.321
49	Barot	B	32°.0227	76°.5024
50	Kalatop	KT	32°.3305	76°.0105

(*DD- Degree Decimal) N* - North and E*- East

Water Holding Capacity (WHC) of these samples varies with respect to pH, the overall mean value is 43.12%. The pattern of WHC is shown as Himachal Pradesh < Uttarakhand < Kashmir < Sikkim and West Bengal. WHC is the maximum at lowest pH and minimum at highest pH. 26 samples out of 50 samples are under the category of low WHC (<45%) and 20 samples in the category of medium WHC (45-60%) and only 4 samples under high WHC (<60%), which shows that the content of Himalayan soil is depriving the organic matter and under critical condition.

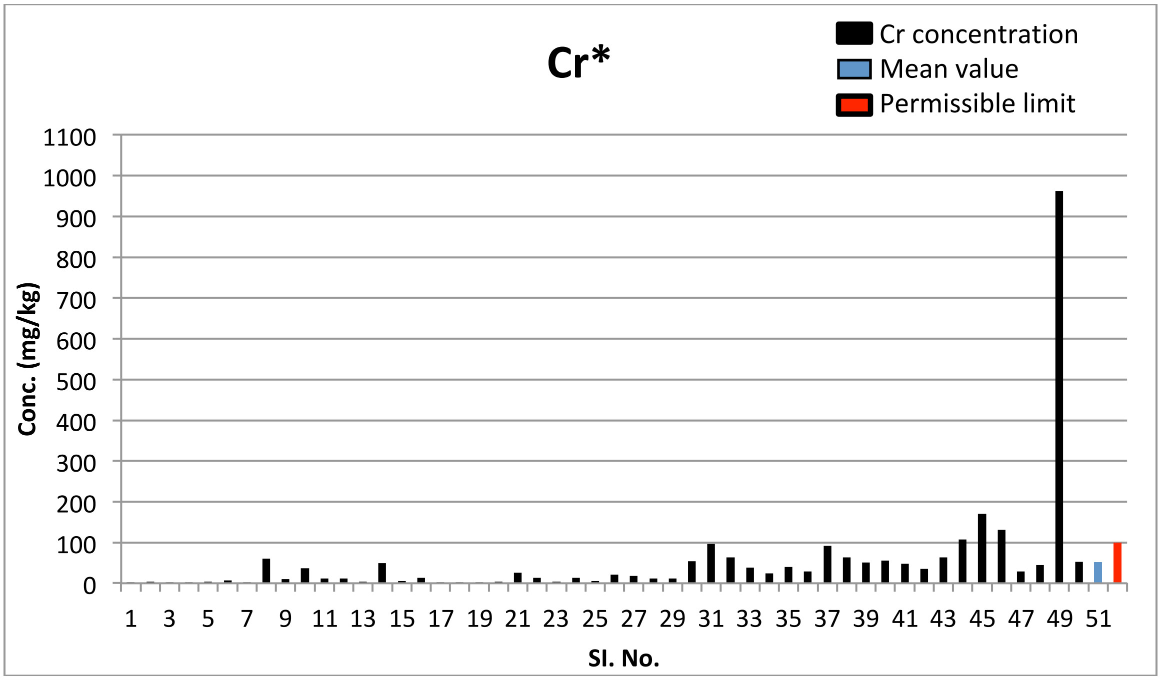

Figure 2: Chromium metal concentrations

Soil polluted with heavy metals might adversely affect the quality of groundwater and causes the harmful effects. The heavy metal concentration in the analyzed soil samples is compared with the WHO and US-EPA limits as given in Table-3 which demonstrate that mean concentration of all the metals is within the permissible limits except Iron, Mercury, and Manganese. On comparison of all soil samples, it is indicated that Cu, Cr, Co and As content is in the certified range but there are elevated levels of Fe, Hg, and Mn i.e 33422.25mg kg^{-1}, 3.2346mg kg^{-1} and 675.687mg kg^{-1}, while their permissible limits are 21,000.00mg kg^{-1}, 0.8mg kg^{-1}, and 320 mg kg^{-1} respectively. The elevated levels of these heavy metals indicate the alarming signal of soil pollution in the Himalayan region. The mean metal concentration of iron is trending as Himachal Pradesh > Uttarakhand > Kashmir > Sikkim and West Bengal samples. Copper, Cobalt, Arsenic, and manganese concentration trend is same as Iron. The Chromium concentration shows the trend as: Himachal Pradesh > Uttarakhand>Sikkim and West Bengal> Kashmir, while, the Mercury concentration trend is shown as: Sikkim and West Bengal>Uttarakhand>Kashmir > Himachal Pradesh. The graphs obtained using concentration of each of the heavy metal in the 50 samples is given in (Figure: 2—8), in which, metal concentration (mg/kg) is plotted against their permissible limits.

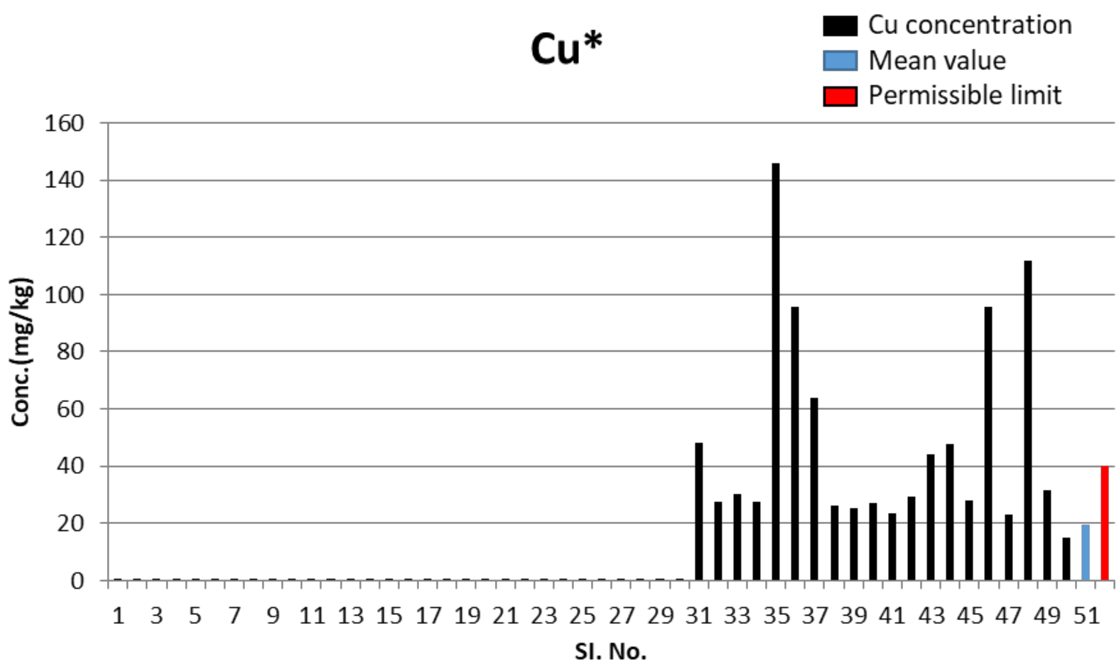

Figure 3: Copper metal concentrations

Bayes factor inference on Pairwise Correlation (IBM SPSS software version 1.0) is used to detect the correlation between various soil parameters. The parameters included are pH, Electrical Conductivity, Water Holding Capacity with concentrations of iron, manganese, arsenic, copper, chromium, cobalt and mercury (Table 4). On the basis of Pearson correlation matrix pH is strongly associated with arsenic as pH increases the concentration of arsenic and manganese concentration also increases, showing a positive significant correlation, while pH has negative correlation with cobalt and iron. The r-value between pH and Fe; pH and Co are -0.039 and -0.079 respectively. The soil pH is in significantly negative correlation with Iron and cobalt content. It can be observed that Iron and cobalt concentration decreases with the increase in soil pH as Iron solubility in soil is highly pH dependent.

EC is in negative correlation with mercury, r-value of -044, while the significantly positive correlation with iron and other selected heavy metals. EC is very strongly associated with iron as EC value increases the value of Fe is also increase with it. Also, electrical conductivity is positively correlated with water holding capacity with the r-value of 0.281.WHC has a strong negative correlation with chromium due to which any significant increase in Cr content decreases the water content of the soil. But there is a positive correlation between Fe and WHC; Cu and WHC; Co and WHC, increase in one variable increase the values of the second variable. Therefore, it indicates that water content greatly influences the Cr availability in the soil as compared to other heavy metals.

Table 2: Represent the various Physico-Chemical parameters of 50 different soil samples of Indian Himalayan Region

Units	**Sample code**	**H^+ Conc.**	**dS/m**	**%w/w**
S.N.		**pH***	**EC** *(dS/m)	**WHC* (%w/w)**
1	MT	5.45	1.01	69
2	ST	5.07	1.11	43
3	TM	5.6	0.96	28
4	KD	5.54	0.82	44
5	GC	5.8	1.05	60
6	KM	6.51	0.93	44
7	DT	5.25	1.04	46
8	YT	5.41	0.88	45
9	BT	4.67	0.83	34
10	CT	5.92	1.19	59
11	JC	5.47	1.37	30
12	HC	5.55	1.12	49
13	BY	5.73	1.19	25
14	MS	4.98	0.9	25
15	GT	8.12	1.02	52
16	B	4.95	1.18	51
17	HZ	5.74	1.11	51
18	V	5.2	1.08	64
19	GS	5.7	0.94	23
20	SC	5.9	0.87	34
21	N	5.62	1.21	42
22	LG	5.31	1.16	39
23	L	4.83	1.52	36
24	MG	5.56	1.35	47
25	YV	4.29	0.75	30
26	YS	4.67	0.89	40
27	CB	5.95	0.91	29
28	KS	5.65	1.01	33
29	SD	6.1	1.22	27
30	TS	5.82	0.89	35
31	GT	5.4	1.36	58
32	GN	5.48	1.49	54
33	LN	5.46	1.23	56
34	KJ	5.38	1.28	42
35	BG	5.42	1.35	47
36	BB	5.41	1.44	43
37	YG	5.47	1.43	55
38	SM	5.37	1.67	48
39	DB	5.4	1.72	41
40	DC	5.41	1.75	43
41	DS	5.38	1.46	46
42	M	5.49	1.18	42
43	J	5.35	1.65	47
44	S	5.87	1.88	25
45	K	5.56	1.87	52
46	BD	5.52	1.85	51
47	GH	5.32	1.1	51
48	VM	5.2	1.9	64
49	B	5.39	0.96	23
50	KT	5.6	0.89	34
51	**Mean**	5.504	1.219	43.12

Mean of triplicates * Electrical Conductivity (EC), Water Holding Capacity (WHC), Iron (Fe), Manganese (Mn) and Mercury (Hg), Cooper (Cu), Arsenic (As), Chromium (Cr) and Cobalt (Co)

Table 3: Represent the various heavy metal concentrations in mg kg-[1] of 50 different soil samples of Indian Himalayan Region

S.N.	Sample code	Fe*	Cu*	Mn*	Cr*	Co*	As*	Hg*	Meter Elevation
1	MT	15478	0.0104	451.09	2.16	2.8	4.4293	1.08903	3284m
2	ST	12536	0.01256	403.78	4.38	6.52	3.5349	0.56201	3496 m
3	TM	8693	0.01172	545.86	0.53	0.48	19.0971	0.85131	3097 m
4	KD	14003	0.02312	367.02	1.23	8.23	12.1635	0.72797	3265 m
5	GC	14418	0.01135	477.23	4.5	4.81	10.4685	0.6719	3142 m
6	KM	18217	0.02138	356.52	6.25	0.22	7.7087	0.99036	3263 m
7	DT	8472	0.01004	390.77	3.09	5.21	2.8535	0.92532	3895 m
8	YT	11547	0.02317	2.99	60.08	1.23	7.879	0.90065	3273 m
9	BT	19224	0.0155	558.23	9.63	6.96	4.5571	1.03297	2092 m
10	CT	29587	0.05349	217.63	36.14	7.96	3.1516	1.37161	2005 m
11	JC	11088	0.01177	282.1	11.38	2.9	0.4259	1.30209	2534 m
12	HC	15143	0.01886	325.37	12.09	1.79	12.879	1.59812	2065 m
13	BY	14241	0.02674	189.55	3.33	2.39	0.3407	1.52635	2189 m
14	MS	9753	0.01361	154.28	48.63	1.63	1.0221	1.58017	2010m
15	GT	5690	0.01035	184.54	6.13	2.74	9.8382	1.64073	2065 m
16	B	19224	0.01392	218.19	13.25	0.82	20.891	1.75286	2053 m
17	HZ	14931	0.01103	2.1	2.98	0.99	2.8109	1.634	2032 m
18	V	20505	0.02359	392.31	3.09	8.03	12.0954	1.89863	2088 m
19	GS	11927	0.02165	205.43	2.51	1.83	3.5775	2.01525	2079 m
20	SC	3348	0.0114	216.09	4.26	0.93	0.1704	2.01301	2012 m
21	N	4417	0.01072	333.57	25.86	6.32	1.9591	2.0915	2128 m
22	LG	17802	0.02438	192.82	12.9	1.03	6.0903	2.62749	2700 m
23	L	7253	0.01408	188.58	3.56	0.22	11.6695	2.41669	2750 m
24	MG	9480	0.00998	194.84	13.6	1.03	1.9591	2.39202	956 m
25	YV	12616	0.01398	191.17	4.73	1.13	7.0855	2.63422	3564 m
26	YS	9073	0.01103	410.85	20.38	8.43	4.3667	2.5759	4200 m
27	CB	15425	0.01928	487.61	17.57	2.9	5.2254	2.4122	2042 m
28	KS	13826	0.02154	217.71	12.32	12.25	1.6412	2.4593	1458 m
29	SD	18915	0.01739	456.7	11.97	3.1	8.7651	2.60731	2152 m
30	TS	16547	0.0351	205.71	54.82	0.4	13.0493	2.64992	4863m
31	GT	78607.00	48.361	1679.425	96.713	28.750	18.673	-0.6603	3415M
32	GN	42905.72	27.736	549.1303	62.818	15.76	3.151	-0.559	3212M
33	LN	38043.79	30.02	440.8667	37.861	14.461	6.218	-0.5803	3157m
34	KJ	29276.87	27.333	754.7697	24.667	7.781	76.168	-0.598	1920m
35	BG	85746.42	145.692	660.2317	40.533	22.065	9.1886	-0.2986	2289m
36	BB	51561.66	95.751	858.743	28.238	18.485	2.0506	0.5286	1989m
37	YG	118656.05	63.6283	2380.377	92.088	31.565	23.839	34.506	3292m
38	SM	52079.62	26.154	992.9733	64.263	13.912	10.782	0.0946	3231m
39	DB	38862.00	25.160	1073.835	50.338	12.254	16.6883	-0.395	2081m
40	DC	42689.80	26.972	1182.172	55.217	15.311	13.765	-0.4396	2085m
41	DS	43173.22	23.512	1651.15	47.048	13.212	12.268	-0.5143	2079m
42	M	43557.11	29.390	1512.352	35.361	13.397	31.798	-0.5806	1456m
43	J	54113.22	44.2743	1488.539	63.875	17.88	119.790	-0.43966	3233m
44	S	114203.55	47.6173	2590.346	108.08	29.202	28.2733	-0.679	2210m
45	K	109939.52	27.894	2250.648	170.85	30.144	34.879	4.3563	2632m
46	BD	103021.47	95.601	1485.073	130.30	18.686	28.821	-0.659	1853m
47	GH	47649.59	22.864	810.3813	28.446	17.13	2.5976	76.441	2730m
48	VM	51703.41	111.749	695.643	44.792	13.468	78.751	1.296	3582m
49	B	79685.01	31.4663	1069.455	962.79	36.869	3.5296	0.17566	1829m
50	KT	42258.90	15.0466	837.6207	52.405	13.922	81.273	-0.215	1923m
51	**Mean**	33422.25	19.3351	675.687	52.201	9.7908	16.0842	3.2346	2579m
52	**Permissible limit**	**21000.00**	**40**	**320**	**100**	**20**	**20**	**0.8**	

Mean of triplicates * Electrical Conductivity (EC), Water Holding Capacity (WHC), Iron (Fe), Manganese (Mn) and Mercury (Hg), Cooper (Cu), Arsenic (As), Chromium (Cr) and Cobalt (Co)

Table 4: Represent the Bayes Pairwise Correlation between various soil Parameters

Bayes Factor Inference on Pairwise Correlations

		pH	EC (µS)	WHC (%w/w)	Fe	Cu	Mn	Cr	Co	As	Hg
pH	Pearson Correlation	1	-0.036	0.056	-0.039	-0.086	-0.033	-0.037	-0.079	-0.053	-0.048
	Bayes Factor		8.764	8.386	8.706	7.582	8.801	8.740	7.793	8.454	8.559
	N	50	50	50	50	50	50	50	50	50	50
EC (µS)	Pearson Correlation	-0.036	1	0.281	0.648	0.597	0.639	0.060	0.526	0.375	-0.044
	Bayes Factor	8.764		1.290	0.000	0.000	0.000	8.300	0.004	0.252	8.626
	N	50	50	50	50	50	50	50	50	50	50
WHC (%w/w)	Pearson Correlation	0.056	0.281	1	0.186	0.261	0.113	-0.194	0.153	0.146	0.132
	Bayes Factor	8.386	1.290		3.941	1.710	6.685	3.644	5.163	5.414	5.952
	N	50	50	50	50	50	50	50	50	50	50
Fe	Pearson Correlation	-0.039	0.648	0.186	1	0.734	0.881	0.432	0.910	0.332	0.182
	Bayes Factor	[illegible]	0.000	3.941		0.000	0.000	0.069	0.000	0.579	4.065
	N	50	50	50	50	50	50	50	50	50	50
Cu	Pearson Correlation	-0.086	0.597	0.261	0.734	1	0.516	0.187	0.648	0.357	0.046
	Bayes Factor	7.582	0.000	1.710	0.000		0.006	3.910	0.000	0.364	8.602
	N	50	50	50	50	50	50	50	50	50	50
Mn	Pearson Correlation	-0.033	0.639	0.113	0.881	0.516	1	0.297	0.827	0.405	0.147
	Bayes Factor	8.801	0.000	6.685	0.000	0.006		1.021	0.000	0.133	5.402
	N	50	50	50	50	50	50	50	50	50	50
Cr	Pearson Correlation	-0.037	0.060	-0.194	0.432	0.187	0.297	1	0.587	0.019	-0.023
	Bayes Factor	8.740	8.300	3.644	0.069	3.910	1.021		0.000	8.954	8.922
	N	50	50	50	50	50	50	50	50	50	50
Co	Pearson Correlation	-0.079	0.526	0.153	0.910	0.648	0.827	0.587	1	0.275	0.191
	Bayes Factor	7.793	0.004	5.163	0.000	0.000	0.000	0.000		1.411	3.750
	N	50	50	50	50	50	50	50	50	50	50
As	Pearson Correlation	-0.053	0.375	0.146	0.332	0.357	0.405	0.019	0.275	1	-0.088
	Bayes Factor	8.454	0.252	5.414	0.579	0.364	0.133	8.954	1.411		7.509
	N	50	50	50	50	50	50	50	50	50	50
Hg	Pearson Correlation	-0.048	-0.044	0.132	0.182	0.046	0.147	-0.023	0.191	-0.088	1
	Bayes Factor	8.559	8.626	5.952	4.065	8.602	5.402	8.922	3.750	7.509	
	N	50	50	50	50	50	50	50	50	50	50

• Bayes factor Null versus alternative hypothesis.

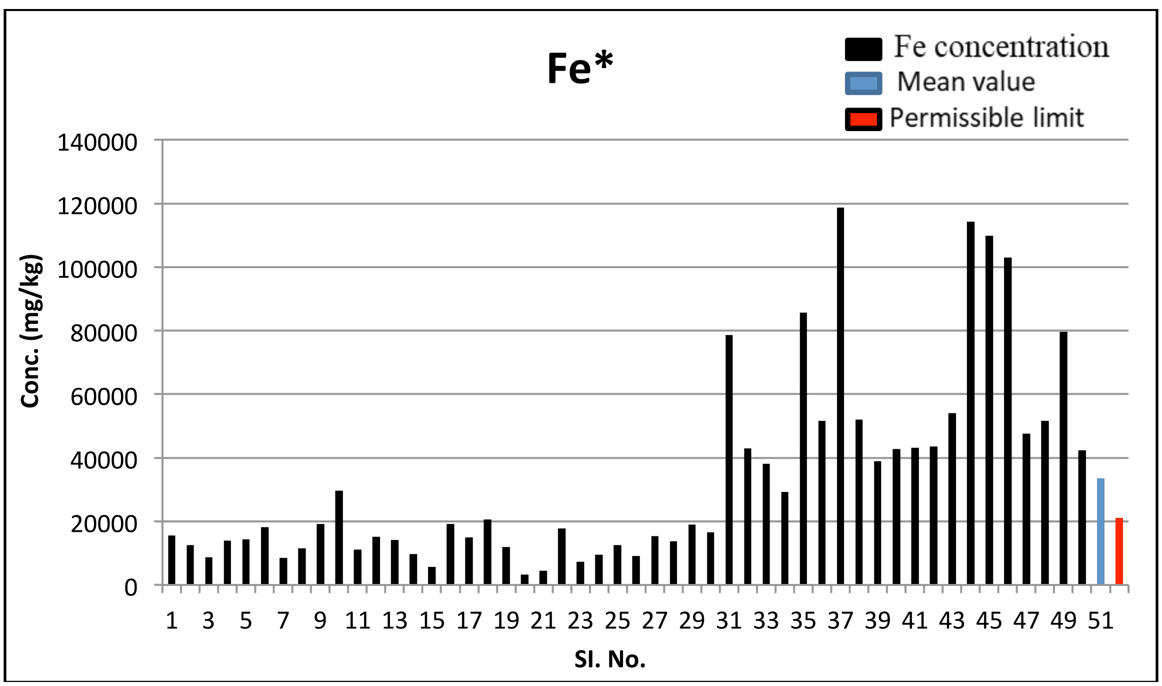

Figure 4: Iron metal concentrations

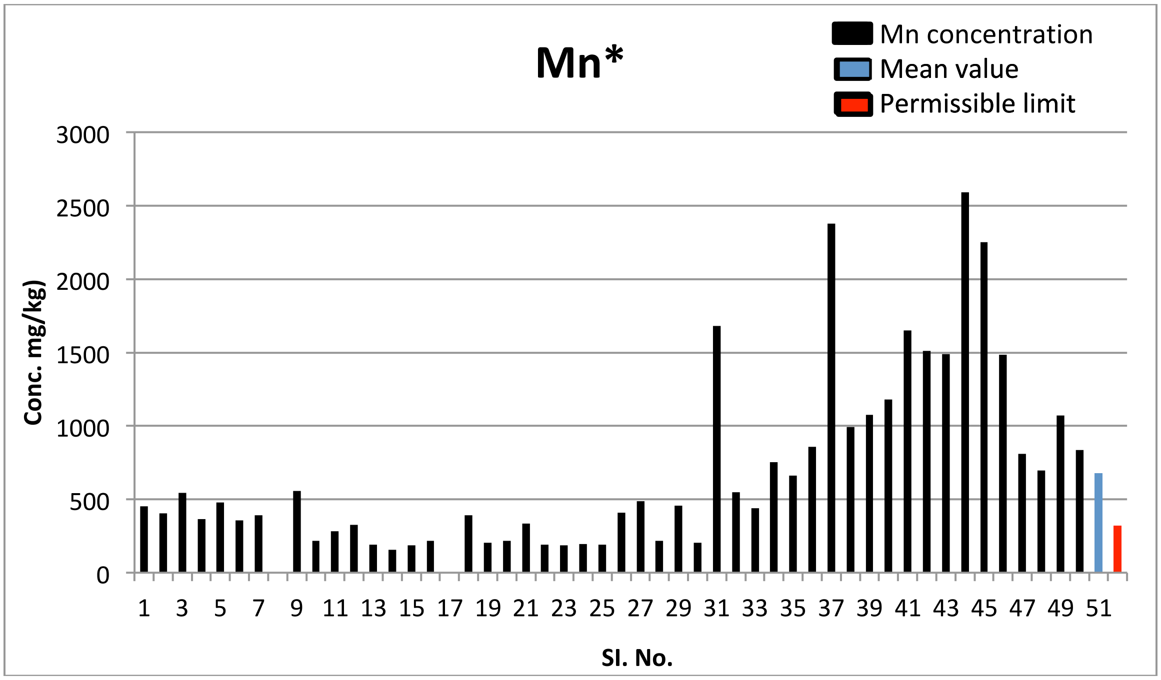

Figure 5: Manganese metal concentrations

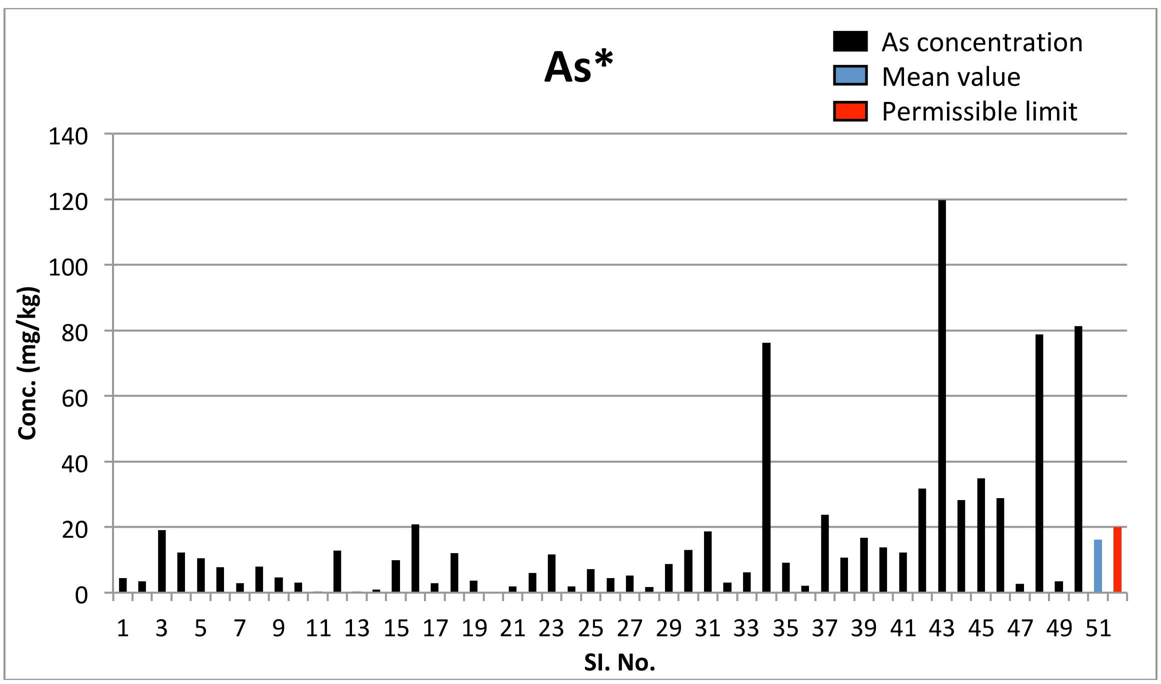

Figure 6: Arsenic metal concentrations

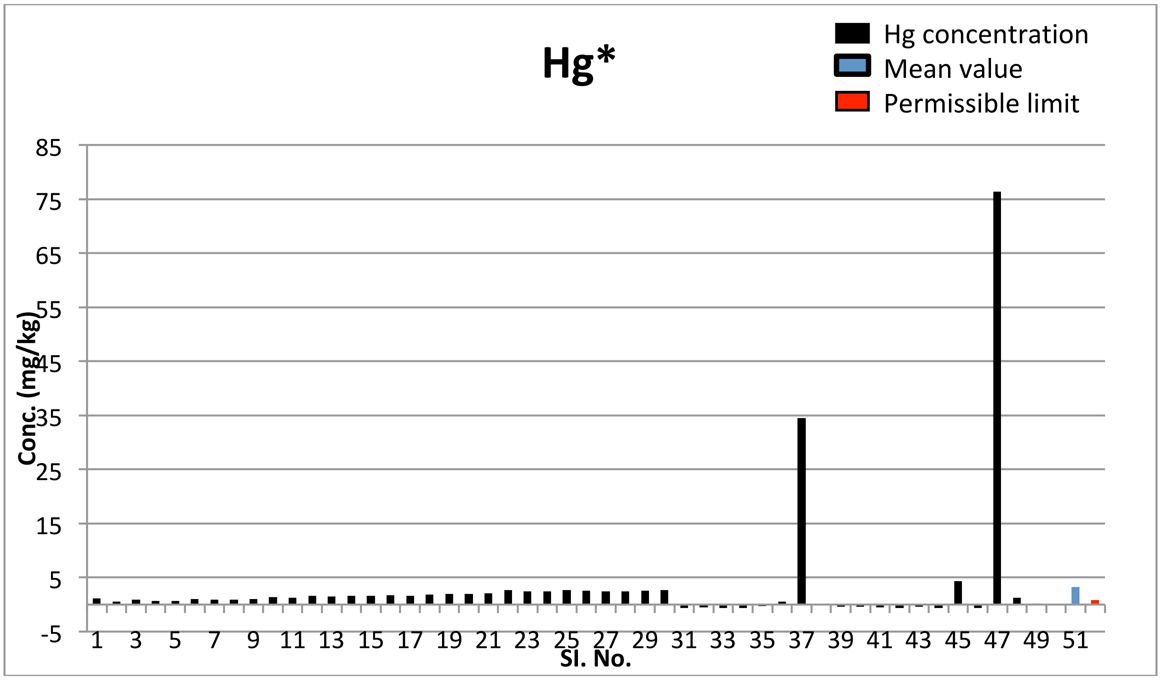

Figure 7: Mercury metal concentrations

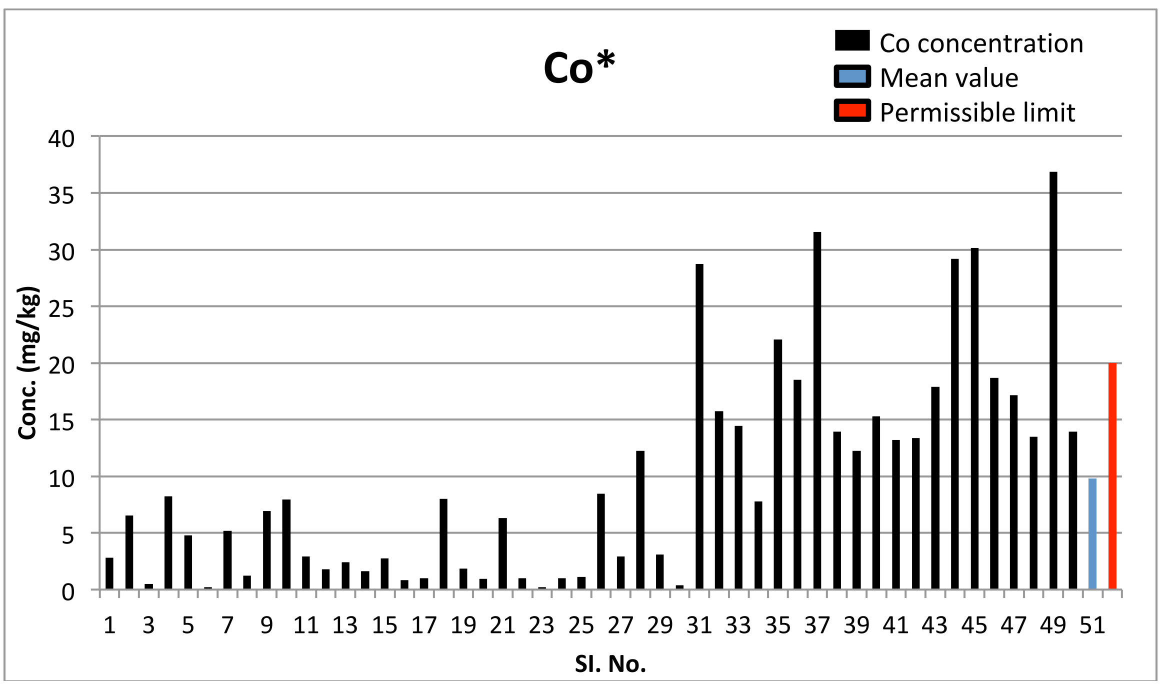

Figure8: Cobalt metal concentrations

Discussion

In present study, 26 samples out of 50 have shown low value of WHC, 20 has shown moderate value and only 4 samples has shown the high value of WHC i.e between 60-80%. WHC of these samples mostly varies with respect to pH and the overall mean value is 43.12%, which shows that the texture of soil is sandy and results in limited storage of water content as earlier study reported by (Longwell *et al*., 1963; Castillo and Torstensson., 2007; Michalec, B., 2012, and Kaur *et al*., 2014). Soil pH gives an indication about the acidic or alkaline behavior of the soil. pH of soil influences many aspects of crop productivity, the chemistry of soil, including the availability of various nutrients and toxic substrates and also the microbial activity (Deb *et al*., 2014). Soil pH may affect the phenology of plant species of Himalayan region by affecting nutrient availability, which is lower at high pH for many essential elements (Ranjitkar, 2013). pH is very important parameter for the growth of plant and other living organism also. The ideal pH range is 6.0 to 6.9 for solubility of important ions present in soil for the uptake of plants (Ackova., 2018). For example, iron and other heavy metal also are easily soluble at low pH, therefore the soil present in Himalayan region due to its acidic nature easily gets contaminated with these toxic heavy metal and cause soil pollution (Osei *et al*., 2010, and Reddy, S.K., 2017). The pH values for different soil samples observed in the present study ranged from 4.29 -8.1 with the mean value of 50 samples is 5.5, which shows the acidic character of the Himalayan soil.

These results are in conformity with earlier studies on the soils of Himalayan region (Khare *et al*., 2014; Nawaj *et al*., 2015; Tewari *et al*., 2016 and Shrestha *et al*., 2017). However in some studies, this range has been compared to the ideal range for rice i.e. 5.5-6.5 (Focht, 1979 and Bandara *et al*., 2005) as in the case of present study. WHC of the soil is defined as the amount of water that a given soil can hold against the gravitational force (Khaled and Fawy, 2011). Texture and organic matter of soil are the two key components which determine the soil water holding capacity (Acharya *et al*., 2014). In hilly areas, topographical and climatic conditions influence the soil properties to a great extent and result in space and time variations with the soil properties like WHC (Sheik and Kumar, 2010; Rajeswar and Khan, 2008). EC gives the standard measure the number of salts present in the soil. It is an important indicator for the detection of soil health (Hiyaly *et al*., 1993). The mean value of EC in present study is 1.129dS/m, i.e less than 2 shows the non-saline nature of soil, and affect the nutrient value of soil and positive significant correlation with most of the heavy metals, which is supported by previous studies (Kamal *et al*., 2009 and Jung, M., 2008).The electrical conductivity of soil affects nutrient mobility and availability for plants, crop yield and also the activity of micro-organism in soil which influence basic soil processes such as emission of gases like nitrogen oxide, carbon dioxide and methane which cause the greenhouse effect and hindered the growth of plants by directly affecting soil-water balance (Grisso, 2009).

Atomic absorption spectroscopy (AAS) technique has been used to achieve the aim of detection and quantitative analysis of heavy metal content in soil, which are particularly useful for the purpose of information related to the genesis of soil and also to check the level of contamination. In the Himalayan soil samples, the mean heavy metals concentration of all the 50 samples were found to be in the range of 3348-118656.10 mg kg-^{1} with the mean of 33422.2586 mg kg-^{1} for Iron. It is significantly high in comparison to studying reported by Llopis *et al*., 2006 in Alicante, Spain with the mean Fe content of 15,274 mg kg-^{1} and range of 10,979-19,807 mg kg-^{1}. It has shown higher values than (Imperato *et al*., 2003 and Chen *et al*., 1997). In the present study, mean value of manganese content in Himalayas is found to be higher (675.687mg kg-^{1}) with range of 2.1-2590.346 mg kg-^{1} than the reported value by Paterson *et al*., 1996 in Scotland Range and chromium content is 0.53-962.791 mg kg-^{1} with mean value of 52.201 mg kg-^{1} in Himalayan region is under the study is lower than the studies reported by (Varun *et al*., 2010) in Firozabad and (Paterson *et al*., 1996) in Scotland. Cobalt mean value in soil i.e. 9.7908 mg kg-^{1} is higher than the reported mean value of 3.70 mg kg-^{1} as (Paul *et al*., 2014) in North Central India, while under the permissible range. Mercury mean concentration in Himalayan soil is found to be higher mean value 3.2346 mg kg-^{1} than the mean concentration of 0.51 mg kg-^{1} as reported by Carey *et al*., 1979. The range of arsenic content 16.0842 mg kg-^{1} in the present study is found to be significantly higher than the range of 9.25-204 mg kg-^{1} reported by Varun *et al*., 2010 in Firozabad. In the present study, the value of Hg, Fe and As are reported higher as in the case of Varies *et al*., 2012; Smedley and Kinniburgh, 2002. High amounts of heavy metals especially Hg, Pb and As in the plants adversely affect the absorption and transport of essential elements, disturb the metabolism, and showed direct impact on growth and reproduction (Xu and Shi, 2000; Sigel and Sigel, 2000; Singh *et al*., 2013 and Nagajyoti *et al*, 2010). Heavy Metal solubility tends to increase at lower pH and decrease at higher pH values (Rieuwerts *et al*., 1998). The concentration levels of all metals fall under the permissible levels except manganese, iron, and mercury in all the soil samples.

The elevated levels of Hg in plants cause various adverse effects on plant morphology and physiology such as root and shoot growth inhibition, decrease in essential element uptake and inhibition of synthesis of photosynthetic pigment (Israr *et al*., 2006). The symptoms of Hg toxicity are stunting, chlorosis and necrotic leaf spots and brown spotting of older leaves (Gupta and Gupta, 1998). In animals, mercury may bind to a variety of enzyme systems within cells including those of microsomes and mitochondria, producing nonspecific cell injury or cell death. Arsenic affects the energy transformation reactions like Krebs cycle, oxidative phosphorylation, ATP production is inhibited and high levels of mercury exposure to fetus result in abnormal neuronal migration and deranged brain nuclei organization and layering of neurons in cortex food (Goyer and Clarkson, 1996). Iron is extremely useful, but can also be highly toxic to cellular constituents when present in excess and it is an important part of the plant's oxidation-reduction reactions. Iron is a structural component of cytochromes and numerous other electron-transfer systems, including nitrogenase enzymes necessary for the fixation of dinitrogen gas (Fendorf and Li, 1996). The major problem with iron availability is how to keep iron sufficiently soluble for plants to absorb enough of it. In strongly acidic solutions (pH < 5), iron becomes increasingly soluble and is rarely deficient (Landis and Yu, 1995).Manganese is an essential element and is a co-factor for a number of enzymatic reactions, particularly those involved in phosphorylation, cholesterol, and fatty acid synthesis (Goyer and Clarkson, 1996). Manganese toxicity and high levels of Mn concentration have normally found in plants growing on strongly acid soils (Gupta and Gupta, 1998) which alter the various enzymatic and hormonal activities in plants so that essential Mn-requiring processes become less active or nonfunctional in plants (El□Jaoual and Cox, 1998). In animals, Manganese overexposure causes reproductive and developmental toxicity, hepatotoxicity, Cardiovascular toxicity, and neurotoxicity i.e. neurochemical changes in the brain (Crossgrove and Zheng, 2004).The sampling sites have higher values of these heavy metals are correlated with their Physico-chemical character such as WHC, EC and pH, etc., indicates increase level of mobility, bioavailability and bioaccumulation of these toxic heavy metals in the biodiversity present in this region via which the concentration of these metals increase in the soil of this region with some other natural processes such as weathering, leaching, etc. while the anthropogenic activities such as illegal mining, deforestation and waste produced by urbanization, industrialization and emission of transport vehicles with increasing tourist influx in these regions are some main source of these heavy metals contamination in the soil of this region (Smith and Ross.,1995 and Wani *et al*., 2012)

Conclusions

This study may be useful for quantitative analysis and monitoring the elevated levels of these toxic heavy metal concentrations in the soil samples of Western and Eastern Himalayan, which contaminate the soil of Indian Himalayan region and polluted it. The results of present study indicates the significant correlation between physico-chemical characters and heavy metal concentrations, which has been used as baseline information for the further analysis of the impact of these toxic metals on macro and micronutrient in soil and species density of Himalayan region. The significant correlation found between physico-chemical parameters and heavy metal concentration implies responsibility of phyto-toxicity due to the mobility and bioavailability of heavy metals for the uptake of plant species mostly. The results indicate the elevated level of Hg, Fe and Mn in the soil of this region implies accountable situation on the anthropogenic activities such as rapidly increasing trends of urbanization, industrialization, globalization, tourist influx and illegal mining are responsible for the soil pollution mostly. These toxic heavy metals also impact on the distribution of flora and fauna present in this region. These results can be further used to analyze the impact of heavy metal on the concentrations of micro and macronutrient present in this region for the growth of mostly pre-dominated plant species and their distribution pattern with the help of remote sensing and GIS data, which especially present at this high altitude. Some plant species present in the Himalayan region has gone into critical and endangered conditions due to increased contamination of these toxic heavy metals, which are found to be responsible for the loss of essential macro and micronutrient in the soil mostly. Hence, it is an essential need of an hour to preserve and conserve the great biodiversity of Indian Himalayan region via some awareness program and strict rules and regulations for industrial, agriculture and anthropogenic wastes and encourage organic farming in spite of increasing trends of fertilizer, insecticides, and pesticides.

Abbreviations: Electrical Conductivity (EC), Water Holding Capacity (WHC), Atomic Absorption Spectrophotometer (AAS), Iron (Fe), Manganese (Mn), Mercury (Hg), Cooper (Cu), Arsenic (As), Chromium (Cr) and Cobalt (Co), United States- Environmental Protection Agency (US-EPA).

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