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GIS MAPPING AND DISTRIBUTION OF HEAVY METALS (Pb, Cd, Cr, Ni) CONCENTRATION IN AGRICULTURAL SOILS OF COLD ARID REGION-LEH (LADAKH)

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ABSTRACT
Heavy metals are regarded as toxic trace elements in the environment. Heavy metal pollution in surface soils is of increasing concern. In this study, 73 soil samples were collected from the surface layers of agricultural lands from the villages located in the watershed in Ladakh. The soil properties and heavy metal (*i.e*., Pb, Cd, Cr and Ni) concentrations in the surface soils were analyzed to evaluate the heavy metal accumulation characteristics of the agricultural fields. The results showed that the Pb and Ni concentrations in the soil ranged from traces to 18.62 and 0.09 to 1.72 mg kg^{-1}, respectively and Cd and Cr are analyzed in traces amount. This study provides useful information regarding heavy metal accumulation in soil to support the safe production of crops in Ladakh. The findings from this study also provide a robust scientific basis for risk assessments regarding ecological protection and food safety.

KEYWORDS: Heavy metal, agricultural land, watershed, Ladakh, food safety.

INTRODUCTION
The heavy metal (HM, also referred to in scientific literature as metalloid) contamination of soil is one of the most pressing concerns in the debate about food security and food safety in developing countries like India. Various heavy metals have been reported to be dangerous to the health of humans and wildlife when they occur in the environment at some high concentrations (Martin 1997; Uba *et al.,* 2009). The level of toxic metals is increasing in the agricultural soils due to over utilization of various chemicals for better yields. The pollutants can include metals, organic wastes and other organic and inorganic substances (Shetty and Rajkumar, 2009). Okunola *et al.* (2011) summarizes the impact of heavy metal from food origin on human health as well as the mechanism of uptake, transformation and bioaccumulation of heavy metals by plants. Some of the heavy metals are extremely persistent in the environment. They are not easily biodegradable and thus their accumulation reaches to critical levels (Khan *et al.,* 2009). Metals have a high degree of toxicity that can be dangerous for both the human and the environment. The soil pollution by heavy metals has received ample attention in the recent decades (Rafiei *et al.,* 2010). Although low concentrations of these metals are naturally found in soils, human activities have elevated their concentrations. Thus, it is very important to assess soil pollution and take the necessary remediation measures (Romic *et al.,* 2007). Mining, industries, road traffic, waste disposal, and agricultural use of fertilizers and chemicals are amongst human activities that can lead to heavy metal contamination of the soil (Karbassi *et al.,* 2016). On the other hand, main natural factors contributing to metal contamination of the soil include volcanoes, fires in forests, and chemical composition of parent materials (Lado *et al.,* 2008). There are several studies in different countries for interpolation and determination of spatial distribution of heavy metals concentrations in soil (Karbassi *et al.,* 2014). Spatial distribution of Cr, As, Cu, Pb, Cd and Hg in Changxing of Zhejiang Province in China was investigated by geo-statistics and log normal Kriging and ordinary Kriging for mapping (Juang *et al.,* 2001). Lado *et al.* (2008) carried out modeling the distribution of eight critical metals (As, Cd, Cr, Cu, Hg, Ni and Zn) in European topsoil. They used regression-Kriging method and accuracy of predictions was evaluated by cross validation method. An environmental geochemical investigation was carried out in and around the Pali industrial development area of Rajasthan to determine the effect of heavy metals (Krishna and Govil, 2004). Preparation of map to show the spatial distribution of metal contents in soils can help decision makers to select suitable areas for various land use. Hence, due to preference of organic produce by tourists and also by locals, it is of utmost importance to determine the pollution of agricultural soils of this area. Thus, the present investigation has tried to bring out the concentration of lead (Pb), cadmium (Cd), chromium (Cr) and nickel (Ni) in agricultural soils of Leh-Ladakh.

MATERIALS & METHODS
Leh has an extremely harsh environment and one of the highest and driest inhabited places on earth (Fig. 1). Leh's climate is referred to as a "cold desert" climate due to its combined features of arctic and desert climates. These include wide diurnal and seasonal fluctuations in temperature, from -40°C in winter to +35°C in summer, and extremely low precipitation, with an annual 10cm to 30cm primarily from snow (Demenge, 2006). Due to high

altitude and low humidity, the radiation level is amongst the highest in the world (up to 6-7 Kwh/mm). The soil is thin, sandy and porous. These combined factors explain why the entire area is nearly devoid of vegetation, with the exception of valley floors and irrigated areas (Demenge, 2006). The study area is a watershed (Figure 2) having ten villages namely *Sumdo, Martselang, Hemis, Changa, Stakna, Chuchot Gongma, Chuchot Yokma, Chuchot Shamma, Stok* and *Matho.*

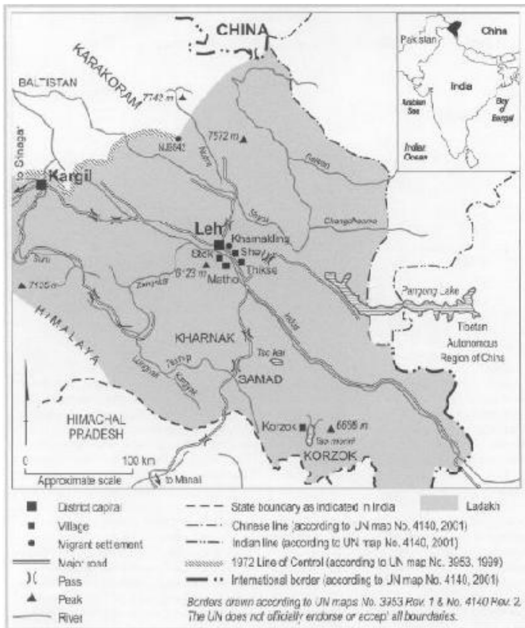

FIGURE 1. Leh Map

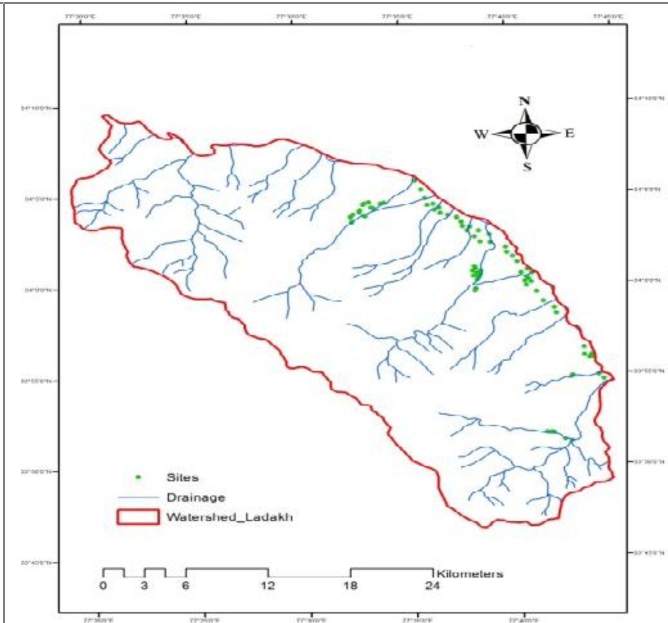

FIGURE 2: Water shed Map

Soil samples were collected from the outer surface *i.e.* 0-15cm depth, after removing surface contamination. Sampling was carried out using a plastic spatula and the use of metal tools was avoided. The samples were collected in self-locking polythene bags and were sealed in double bags. Figure 2 shows the location of soil samples collected from the watershed area. Soil samples were air-dried for few days in shade. The dry soil sample was disaggregated with mortar and pestle. Soil reaction of the soil samples was determined in 1:2.5 soils: water suspension (w/v) with the help of glass electrode pH meter (Jackson, 1973). Electrical conductivity was estimated in 1: 2.5 soil: water suspension with EC meter as given by Chopra and Kanwar (1991).Organic carbon was analysed with the help of rapid titration method as proposed by Walkley and Black (1934). Mechanical analysis of soil was done by hydrometer method using bouyoucous hydrometer as outlined by Piper (1966) and texture of the soil was computed following textural diagram. The extractable heavy (Pb, Cd, Cr and Ni) contents of the soil were determined in atomic absorption spectrophotometry Model, Z2300 (Hitachi), by taking 1:2 DTPA (0.005M; pH 7.3). The thematic maps were produced using the ArcGIS 10.0 software.

RESULTS & DISCUSSION

Soil physical and chemical properties are complex, often non-linearly related, and spatially and temporally dynamic. The distribution of physico-chemical properties in the soil influences the inherent capacity of soil to supply nutrients to plants (Singh *et al.,* 1989). The sand content ranged from 53.61 to 65.83 percent with mean value of 59.36 percent and Clay content was varied in the soils from 11.04 to 17.40 percent (mean 13.82 percent) representing the cold arid soils as sandy loam texture (Table 1).

TABLE 1. Particle size distribution of surface soils of Stok-Hemis watershed

S.No.	Location	No. of sites	Sand		Silt		Clay		Textural Class
			Range	Mean	Range	Mean	Range	Mean	
01	Sumdo	05	53.82-60.11	58.07	26.56-33.06	29.47	11.18-13.33	12.45	Sandy loam
02	Martselang	02	57.89-60.33	59.11	26.63-28.85	27.74	13.04-13.25	13.15	Sandy loam
03	Hemis	02	55.90-56.33	56.11	30.63-32.84	31.74	11.26-13.04	12.14	Sandy loam
04	Changa	05	58.11-60.18	59.33	26.34-26.85	26.56	13.18-15.47	14.11	Sandy loam
05	Stakna	12	59.75-65.83	62.97	20.56-24.92	22.73	11.40-17.25	14.30	Sandy loam
06	Chuchot Gongma	08	57.90-62.11	60.04	20.48-27.13	24.43	13.32-17.40	15.52	Sandy loam
07	Chuchot Yokma	09	57.82-60.11	59.36	24.70-30.42	27.29	11.47-15.33	13.34	Sandy loam
08	Chuchot Shamma	05	55.75-60.12	58.04	24.56-27.06	25.86	15.18-17.26	16.10	Sandy loam
09	Stok	14	53.61-58.32	56.54	26.77-34.70	29.93	11.27-15.40	13.53	Sandy loam
10	Matho	11	57.97-62.11	60.36	24.70-30.42	26.92	11.04-15.18	12.71	Sandy loam
Overall Range and mean			53.61-65.83	59.36	20.48-34.70	26.82	11.04-17.40	13.82	Sandy loam

TABLE 2. Physico-chemical properties of surface soils of Stok-Hemis watershed

S.No.	Location	No. of sites	pH (1:2.5)		EC (dSm^{-1})		OC (%)	
			Range	Mean	Range	Mean	Range	Mean
01	Sumdo	05	8.16-8.35	8.23	0.319-0.465	0.365	0.45-1.95	1.11
02	Martselang	02	8.49-8.65	8.57	0.428-0.452	0.440	0.9-1.2	1.05
03	Hemis	02	8.14-8.32	8.23	0.396-0.417	0.406	2.01-2.37	2.19
04	Changa	05	8.53-8.81	8.68	0.260-0.520	0.368	1.23-1.80	1.61
05	Stakna	12	8.33-8.74	8.55	0.200-0.884	0.426	0.30-2.40	1.07
06	Chuchot Gongma	08	8.00-8.77	8.59	0.107-0.453	0.347	0.15-1.29	0.68
07	Chuchot Yokma	09	8.43-9.21	8.77	0.056-0.633	0.387	0.30-1.20	0.72
08	Chuchot Shamma	05	8.54-8.93	8.76	0.236-0.950	0.418	0.60-1.23	0.82
09	Stok	14	7.52-8.62	8.35	0.039-0.556	0.332	1.02-1.74	1.27
10	Matho	11	8.19-8.71	8.52	0.151-0.390	0.313	0.39-1.77	1.00
Overall Range and mean			7.52-9.21	8.54	0.039-0.950	0.369	0.15-2.40	1.06

TABLE 3. Toxic elements concentration (mg kg^{-1}) in surface soils of Stok-Hemis watershed

S.No.	Location	No. of sites	Pb		Ni		Cd	Cr
			Range	Mean	Range	Mean	Mean	Mean
01	Sumdo	05	6.10-14.67	9.13	0.22-1.02	0.71	Traces	Traces
02	Martselang	02	5.44-6.10	5.77	0.86-1.24	1.05	Traces	Traces
03	Hemis	02	4.56-9.94	7.25	0.60-0.67	0.63	Traces	Traces
04	Changa	05	5.00-10.71	8.29	0.25-0.92	0.58	Traces	Traces
05	Stakna	12	Traces -16.31	8.35	0.09-1.34	0.49	Traces	Traces
06	Chuchot Gongma	08	2.69-15.22	8.69	0.15-1.21	0.71	Traces	Traces
07	Chuchot Yokma	09	5.11-18.62	10.36	0.12-1.72	0.83	Traces	Traces
08	Chuchot Shamma	05	6.54-15.33	12.27	0.25-1.05	0.67	Traces	Traces
09	Stok	14	3.03-17.74	10.92	0.09-1.47	0.75	Traces	Traces
10	Matho	11	7.96-14.78	9.92	0.09-1.37	0.64	Traces	Traces
Overall Range and mean			Traces -18.62	9.58	0.09-1.72	0.68	Traces	Traces

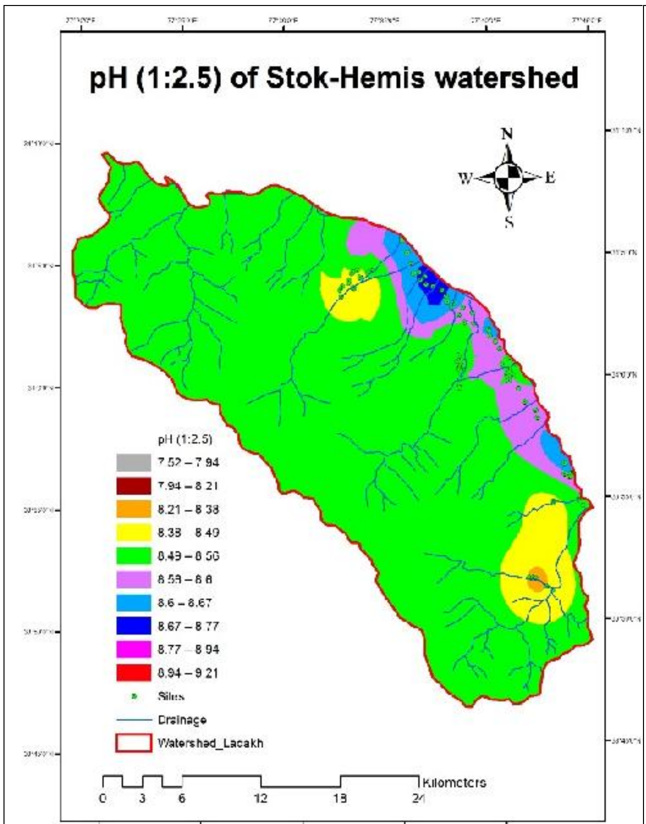

FIGURE 3a P^H

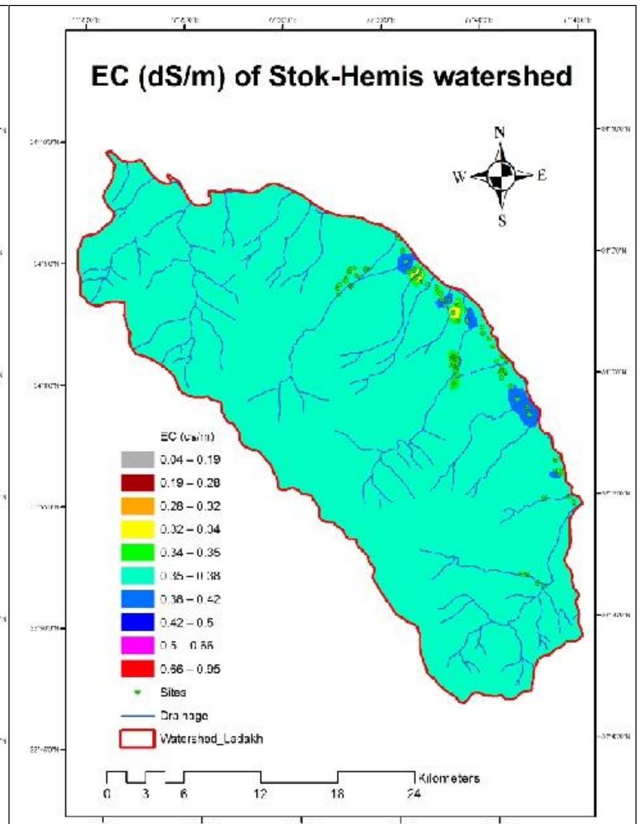

FIGURE 3b EC

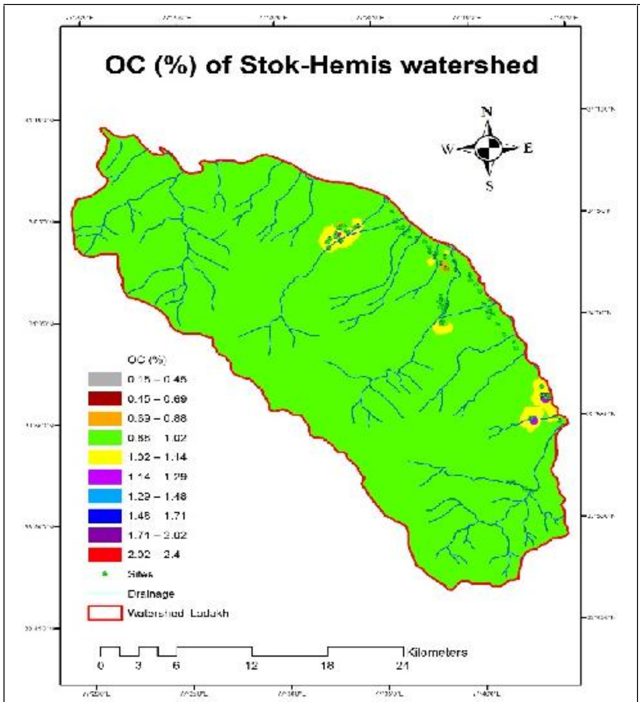

FIGURE 3c Organic Carbon

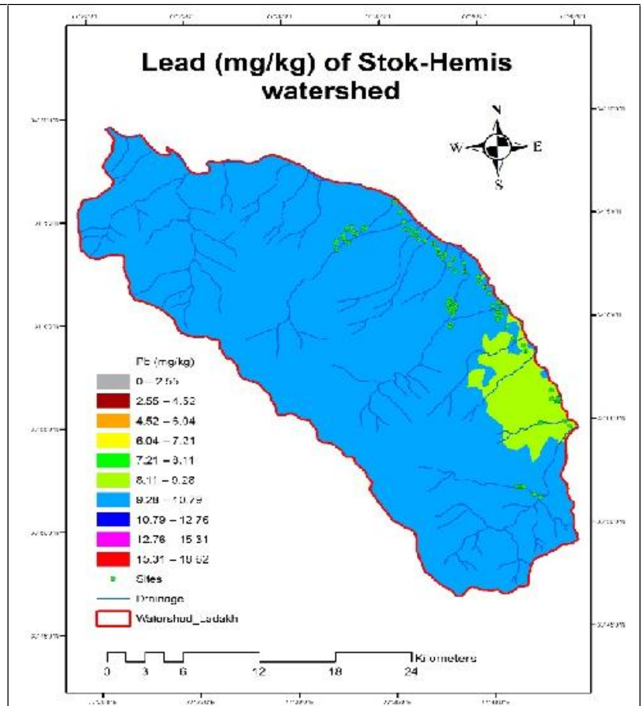

FIGURE 3d Lead

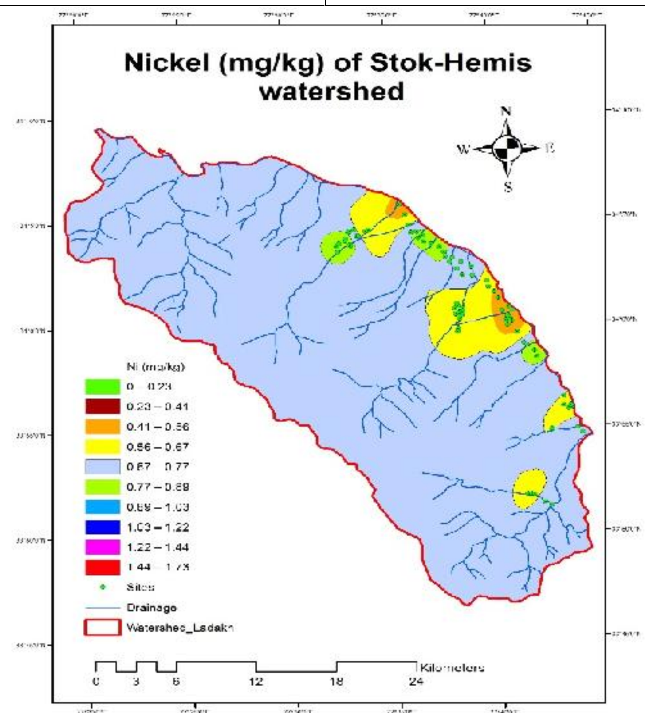

FIGURE 3e Nickel

Soils of cold desert high altitude have originated from weathered rocks, they are immature and with large proportion of sand gravel and stone in them (Dwivedi *et al.*, 2005). Hence, the soils of studied region have more proportion of coarse grained soil particles, which indicates the slow process of soil formation. This may be due to the climatic conditions (low temperature, higher snowfall). Similar observation was also obtained by Acharya *et al.* (2012) and Charan *et al.* (2013) in cold desert soils of Ladakh. Soils of the district were alkaline and, in general, pH varied from 7.52 to 9.21 with a mean value of 8.54 (Table 2; Figure 3a). Single cropping system, extreme low precipitation and high sunlight intensity of this cold arid region could be some of the factors responsible for the alkaline nature of pH in soils. The electrical conductivity (Figure 3b) in the soils is low and was ranged from 0.039 to 0.950 dS m^{-1} (mean 0.369 dS m^{-1}). These results were in concomitant with the findings of Meena *et al.* (2013) and Lelago *et al.* (2016). The average soil organic carbon (SOC) content in the soil samples from the cold arid watershed was 1.06 percent, ranging from 0.15 to 2.40 percent (Figure 3c); these values are similar to those obtained by Jalali *et al.* (1989), Ramesh *et al.* (2015) and Singh *et al.* (2016). Table 3 presents the heavy metal concentrations in the cold arid (Ladakh) samples. The concentration of extractable micronutrients were found to be in the order Pb >Ni> Cd = Cr in all agricultural soils of the study area. Soil lead levels ranging from traces to 18.62 mg kg^{-1} with a mean value of 9.58 mg kg^{-1} (Table 3; Figure 3d). Mean value of normal distribution of lead in the Indian soil is 29 mg kg^{-1}. This high value in cold arid Ladakh may be attributed to weathering of parent material. The presence of lead reduces the enzymatic activity of the biota, and in consequence, incompletely decomposed organic material accumulates in the soil (Ferguson 1990). Lead is the least mobile element among toxic metals, which is attributed to binding of the metal to organic matter (Nagaraju and Karimulla, 2002). The organic matter finally binds the lead in complexes and removes it from water by absorbing into the soil (Govil *et al.,* 2001). Pb impedes the synthesis of hemoglobin and accumulates within the red cells as well as the bones to give rise to anemia, headache and dizziness. Similarly, the concentration of extractable Ni content ranged from 0.09 to 1.72 mg kg^{-1} with mean values of 0.68 mg kg^{-1} (Table 3). The other heavy elements like cadmium (Cd) and chromium (Cr) were found in traces amount in all the soils of the study area. Similar range of these elements has been reported by Nazir *et al.* (2015) and Patel *et al.* (2015).

CONCLUSION

Food chain contamination by heavy metals has become a burning issue in recent years because of their potential accumulation in biosystems through contaminated water, soil and irrigation water. The main objectives of this study were to determine the levels of heavy metals in surface soil of Ladakh. The study showed that the concentration of heavy metals in the soils of agricultural fields was below the critical limit and is of not much concern. However, for better crop productivity, more organic matter should be added to the soils. The traditional nutrient cycling practices, such as manure application, allow crop residue to decay on fields, fallowing and rotational cropping has to be followed to rehabilitate the soil and buildup both macro and micronutrients to their best level.

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