# STUDIES ON CERTAIN ESSENTIAL MINERALS STATUS AND HEAVY METALS PRESENCE IN SOIL, PLANT, WATER, AND ANIMALS AT HIGH ALTITUDE COLD ARID ENVIRONMENT

***A THESIS SUBMITTED IN FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY***

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***TO***

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**WAKNAGHAT, SOLAN- 173 215, HIMACHAL PRADESH, INDIA**

*By*

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May, 2013

# DECLARATION

I certify that,

The work contained in this thesis is original and has been done by me under the guidance of my supervisors. The work has not been submitted to any other organization for any degree or diploma. Whenever, I have used materials (data, analysis, figures or text), I have given due credit by citing them in the text of the thesis.

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# CERTIFICATE

This is to certify that the thesis entitled, **"Studies on certain essential minerals status and heavy metals presence in soil, plant, water, and animals at high altitude cold arid environment"** which is being submitted by **Guru Charan, Enroll No. 086558** in fulfillment for the award of degree of Doctor of Philosophy in Biotechnology by the **Jaypee University of Information Technology**, is the record of candidate's own work carried out by him under our supervision. This work has not been submitted partially or wholly to any other University or Institute for the award of this or any other degree or diploma.

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| | |
|---|---|
| ANOVA | Analysis Of Variance |
| BD | Bulk Density |
| BIS | Bureau Of Indian Standard |
| CCME | Canadian Council Of Ministers for Environment |
| CDHA | Cold Desert High Altitude |
| CDL | Critical Deficiency Level |
| COD | Chemical Oxygen Demand |
| CTL | Critical Toxicity Level |
| DM | Dry Matter |
| DMRT | Duncan Multiple Range Test |
| EC | Electrical Conductivity |
| ESR | Hyper Arid Ecosystem |
| Ft. amsl | Feet Above Mean Sea Level |
| GPS | Global Positioning System |
| HF | Hydrofluoric Acid |
| ICMR | Indian Council Of Medical Research |
| ICP-OES | Inductively Coupled Plasma-Optical Emission Spectroscopy |
| m. amsl | Meter Above Mean Sea Level |
| MAP | Mean Annual Precipitation |
| MAT | Mean Annual Temperature |
| MPL | Maximum Permissible Limit |
| NAS | National Academy Of Science |
| NRC | National Research Council |
| PPM | Part Per Million |
| $r^2$ | Correlation Coefficient |
| SE | Standard Error |
| SIC | Soil Inorganic Carbon |
| SOC | Soil Organic Matter |
| SOM | Soil Organic Matter |
| TDS | Total Dissolved Salts |

| | |
|---|---|
| USEPA | United States of Environmental Protection Agency |
| w/v | Weight/Volume |
| WHO | World Health Organization |

# ABSTRACT

The present study was conducted in Leh-Ladakh a high altitude place where extreme climatic (subzero temperature, lower $O_2$ pressure, low relative humidity, high wind velocity, higher UV exposure, cold aridity, permafrost) and topographical (3500 to 6500 m. amsl altitude) conditions alters physical, chemical, and biological activities of soil and water and affects productivity of plants and animals. Therefore, the present study was conducted with the objectives to generate the reference data for level of essential minerals and heavy metals in soil, water of different sources, feed and fodders, and animals. This investigation finding will help in minerals (Fe, Mg, Mn, Zn, Co, Cu, and B) health assessment of soil, water, feed, and animals and required ameliorative measures. These data will also help in mineral nutrient management for the crop production and feeding balanced diet to the large and small ruminants through supplementation of required minerals. Further, heavy metal (As, Cd, Pb, Ni, and Cr) status at high altitude would facilitate in development of any remedial measures to reduce their presence in human and animal food chain.

To analyze physico-chemical properties (clay, sand, silt, pH, EC, BD, TDS, $CaCO_3$ and SOM) in soil, total 114 composite agriculture soil samples [Site I: (10000-11000 Ft. amsl), 38 sample; Site II (>11000-12000 ft.amsl), 38 sample; and Site III (>12000 ft. amsl), 38 samples] were collected. For analysis of soil carbon content and storage, total 25 composite agriculture soil samples were collected from each altitude gredints, viz: site-I (10,000- 11,000 ft. amsl), site-II (>11,001-12,000 ft. amsl) and site-III (>12,000 ft. amsl). To analyze essential minerals in soil, total 66 composite soil samples from pasture land (06 from each sampling site, total site: 11), total 96 samples from road side soils (06 from each sampling site, total site: 16), and 66 samples from Indus river sediment (06 from each sampling site, total site: 11) were collected. However, to estimate level of heavy metals in agriculture soil, total 06 samples were collected from each 11 study sites. To analyze physico-chemical properties, essential minerals and heavy metal presence in different sources of water, total 66 samples were collected from irrigation (total eleven sites and six samples from each site) and stagnant water (total eleven sites and six samples from each site), while 42 samples (total seven sites and six samples from each site) were collected from Indus River. To study interrelationship among different essential minerals (Fe, Mg, Mn, Zn, Co, Cu, and B) in soil, plant and animals, a total of 54 composite agricultural soil samples (06 from each sampling site, total site: 09), 06 fodder samples of *Medicago sativa* and *Triticum aestivum* were collected from each 09 sites, whereas total 90 blood samples were collected to analyze above minerals from native female Changthangi sheep (10 samples from each 09 villages) and 60 samples from native female Changthangi goat (10 samples from each 06 village). However, for the correlation study among different heavy metals present in plant and animals, total 06 *Medicago sativa* and *Triticum aestivum* plant samples from nine study site, 60 blood samples from native female Changthangi sheep and female Changthangi goat (10 samples from each 06 villages) were collected.

Sand percentage in soil was significantly high at site III and decreased gradually with the altitude. In contrast to sand level, silt concentration was high at site I and decreased significantly ($P<0.05$) with increasing altitude. There was no significant ($P<0.05$) difference in bulk density (BD) and electrical conductivity (EC) among all study sites. However, the highest pH, total dissolved solid (TDS), and $CaCO_3$ value was recorded at site I while higher soil organic matter (SOM) was at site III. Pearson correlation coefficient analysis showed the negative correlation ($P<0.01$, $P<0.05$) of clay, silt, and pH, whereas positive correlation of sand and SOM ($P<0.01$) with altitude. Hence, our findings suggest the altitudinal variations in soil physico-chemical properties at cold desert high altitude.

Soil organic carbon (SOC) content and storage increased significantly with the increase in the altitude where as when compared with the altitude of 10000 ft. amsl, soil inorganic carbon (SIC) content and its storage decreased significantly ($P<0.05$) at an altitude of 11000 upto 12000 ft. amsl. The SOC content and storage were observed positively ($P<0.01$) correlated with altitude, while soil inorganic carbon storage and contents were negatively ($P<0.05$) correlated with altitude.

Our experimental results revealed that, the average concentration of Fe and Mg were 32027.22±2026.57, 32068.36±1787.15, 36099.88±1062.07 mg/kg and 6324.91±584.89, 4416.40±312.91 and 3249.01±337.40 mg/kg respectively in pasture land, River sediments and road side soils. The total mean values of Mn 583.33±34.21, 661.28±118.77, 582.99±20.71 mg/kg; Zn 84.87±7.9, 191.86±143.95, 79.14±4.39 mg/kg; 80.10±7.06, 151.62±103.89, 36.41±2.53 mg/kg of B respectively in pasture land, River sediments and road side soils were estimated. Results of our study indicated that the Fe, Mg, Mn, Zn and B were found within the normal range of soil and further they found above the critical deficiency level in all studied soils.

The total mean concentration of Fe, Mg, Mn, Zn and B in irrigation water were reported to 0.360±0.04, 6.966±0.29, 0.058±0.006, 0.220±0.034, and 1.332±0.09 ppm respectively.

Statistical analysis revealed that, significantly (P<0.05) higher contents of Fe, Mg, Mn, Zn and B in irrigation water were reported to 1.032±0.16, 9.695±0.32, 0.046±0.002, 0.879±0.355, 2.516±0.13 ppm respectively at site 1. Our findings disclosed that, total average values of Fe, Mg, Mn, Zn, and B were examined to 0.403±0.05, 7.832±0.39, 0.055±0.005, 0.332±0.083 and1.346±0.10 ppm respectively in stagnant water. Their range differed from 0.020-1.884, 2.323-16.320, 0.027-0.209, 0.018-5.188 and 0.122-4.745 ppm respectively in stagnant water. The essential minerals (Fe, Mg, Mn, Zn and B) in Indus River water were differed widely and observed to be ranged from 0.087-3.005, 3.593-11.00, 0.030-0.129, 0.065-6.718 and 0.323-2.457 ppm respectively. Whereas, total average concentrations were reported to 0.581±0.11, 8.181±0.25, 0.047±0.004, 0.341±0.188 and 1.467±0.11 ppm respectively in Indus River water. The results revealed that most of the mineral elements were below the optimum level, under the maximum permissible limit and water sources from this region.

Present finding revealed that, total mean concentrations of Fe, Mg, Mn, Zn, Cu, Co and B in agriculture soil were examined to 48475.40±1208, 2424.02±130, 637.49±16.24, 86.67±2.85, 38.80±1.22, 19.947±0.41 and 80.13±3.51ppm on dry matter basis respectively. Whereas, total mean level of these mineral elements in *Medicago sativa* L., *Triticum aestivum* L. straw were observed to 183.23±27.5, 2598.78±94.3, 61.71±3.4, 51.09±3.42, 29.93±2.30, 0.497±0.02 and 17.452±1.72 ppm; 126.28±9.1, 1516.95±68.4, 67.66±4.1, 36.01±1.95, 15.06±0.53, 0.622±0.03 and 11.497 ±0.96 ppm respectively. Further, total average concentration of Fe, Mg, Mn, Zn, Cu, Co and B in serum samples of native sheep and goats were reported to 13.62±1.6, 25.43±0.74, 7.69±0.3, 1.74±0.12, 0.407±0.04, 2.796±0.325 and 6.01±0.59 ppm; 11.54±2.50, 24.01±1.28, 6.84±0.55, 0.421±0.07, 3.328±0.62, 1.48±0.13 and 6.23±0.92 ppm respectively. Pearson correlation coefficient (r) analysis unveiled that, Mg level in soil was significantly (P<0.01) positively (r=0.420**) correlated with their level in *Medicago sativa* L. and significantly (P<0.05) negatively (r=-0.356*); level of Zn in *Triticum aestivum* L. straw was significantly (P<0.05) negatively (r=-0.368*) correlated with their level in native sheep; Mn in wheat straw significantly (P<0.01) negatively (r=0.478**) correlated with their level in goat, and also Fe and Co concentrations in *Medicago sativa* L. were found to be significantly (P<0.01) positively (r=0.394*; 0.394*) correlated with their levels in serum samples of goat. The Fe content in soil was examined to significantly (P<0.05) negatively (r=-0.213*) correlated with their content in sheep.

Total mean concentrations of Ni, Cr and As were determined to be 75.533±6.72, 19.947±0.41, 8.824±1.42 mg/kg respectively in agriculture soil. While the other metals (Pb and Cd) were not detected. Ni was found above the threshold limit in soil whereas other metals were below the threshold limit. The present study reported that the heavy metals (Ni, Cr and As) are widely distributed in agriculture soil at cold arid high altitude and it indicates that the geological system, rocks and the parent material of this microclimate have the heavy metals forming minerals.

The total mean values of pH (7.58±0.04), EC (243.78±18.05 µS/cm), Salinity (0.12±0.01%), TDS (121.519.75 mg/l), turbidity (1.17±0.22 NTU) and COD (31.45±0.73 mg/l) of Indus River water were determined, while of irrigation water, pH (7.43±0.05), EC (231.86±11.00µS/cm), Salinity (0.11±0.01%), TDS (113.31±5.48 mg/l), turbidity (0.85±0.11NTU) and COD (29.74±0.49 mg/l) and of stagnant water pH (7.46±0.03), EC (233.14±11.41µS/cm), Salinity (0.12±0.01%), TDS (115.03±5.78 mg/l), turbidity (0.67±0.13 NTU) and COD (29.65±0.57 mg/l) were reported. Variance in the range of heavy metals of Indus River water were determined to 0.001-0.099 ppm (As), 0.019-0.045 ppm (Cd), 0.039-228 (Pb), 0.020-0.035 ppm (Cr), 0.001-0.051 (Ni), while in irrigation water, As (0.006-0.201 ppm), Cd (0.012-0.036 ppm), Pb (0.043-0.275 ppm), Cr (0.019-0.275 ppm), Ni (0.001-0.062 ppm); stagnant water As (0.002-0.121ppm), Cd (0.019-0.049 ppm), Pb (0.039-0.229 ppm), Cr (0.020-0.220 ppm) and Ni (0.001-0.043 ppm) were estimated.

The total average values of Ni, Cd, Cr, Pb and As, were determined to 0.500±0.04, 0.500±0.04, 12.613±0.96, 0.111±0.07, 0.096±0.02 ppm respectively in *Medicago sativa* L. samples, while in *Triticum aestivum* L. straw, these were examined to 0.457±0.04, 0.237±0.02, 33.174±4.41, 0.064±0.01 and 0.004±0.001 ppm respectively. The average concentration of Ni, Cd, Cr, Pb and As were determined to 2.021±0.124, 0.303±0.04, 10.171±0.219, 3.337±0.32, 1.731±0.377 ppm respectively in serum samples of Changthangi sheep, whereas 1.747±0.17, 0.750±0.13, 9.866±0.34, 3.322±0.54 and 0.167±0.003 ppm of Ni, Cd, Cr, Pb, As were examined respectively in native goat serum samples. Correlation analysis revealed that most of the heavy metals were observed to have correlation between forages and animals but calculated statistically non-significant ($P<0.005$; $P<0.001$).

REALIZATION OF SOUL IS THE ONLY WAY TO SPIRITUAL PATH

# This Manuscript is dedicated to My Dadda

# &

# Farmers of Leh-Ladakh

# CHAPTER I

# Introduction

Mineral status (essential minerals and heavy metals) of soil and water has influence on plant minerals concentration and minerals intake of animals. There is definitive role of minerals deficient soils in causing deficient levels in ration [McDowell and Conrad, 1990]. There is a complex relationship between soil, plant and animals due to specific characteristics of the plants and minerals interactions among the different minerals [Bhat et al., 2011]. In the nature a definitive cycle of minerals nutrients transfer occurs between soil and plants, plant and animals and animals to soil [Bhat et al., 2011]. Many minerals which play important roles in a wide variety of biological processes of living systems are called essential minerals. Homeostasis of these minerals is maintained through tightly regulated mechanisms of uptake, storage and secretion. It is therefore critical for life and is maintained within strict limits. Hence, breakdown of minerals homeostasis can lead to the deficiency or toxicity of particular minerals and may affect health and productivity of animals. Similarly, presence of certain heavy metals in different sources of water in plain areas is one of the most important problems that have received attention at regional, local and global levels because of their toxicological aspect in ecosystems and public health. However, no studies have been done to evaluate these metals in water sources of high altitude (Himalayan region).

In India dietary concentration of minerals in the fodder fed to the animals are unknown or highly variable due to availability, season, location, forage species, status in the animals [Sharma et al., 2003]. So, it is important to determine region wise mineral concentrations in animals to evaluate livestock minerals requirement. The essentiality of minerals in animal's feed can not be denied as they play crucial role in growth, milk production, reproduction and normal physiological functions of animal body. However, there is greater degree of uncertainty in the mineral requirements of animals depending upon age, breed, and level of production, dietary antagonist, animal adaptation and interrelationship with other nutrients [Engle et al., 2001]. In India, the supply of macro-minerals often comes largely from pasture herbage, hay and straw based diets which are found to be on border line for these macro-minerals. Moreover, these are high in silicate, oxalates and tannins which interfere with the utilization of these nutrients [Khan et al., 1999].

The mineral status of fodder may be altered by plant species, stage of harvesting, season of the year, fertilizers application rate, soil type and soil pH [McDowell, 1997]. Furthermore, there is great degree of variation in the minerals profile of water obtained from various sources in different seasons. There are other animal factors and mineral interactions which also play an important role [Khan, 1999]. For several decades, biochemical measurements of the minerals in soil, water, plant and animal tissue or fluid have been analyzed but the task is a challenging one in view of diverse nature of soil and agro-climatic conditions. The quality and quantity of nutrients of forage mainly depend on irrigation water quality. Mineral availability, particularly trace elements, varies to a very great extent from soil to plants and plant to animals. Micronutrients are depleted from light textured and calcareous soils, particularly high yielding crops varieties are grown under intensive cropping system [McDowell and Valle, 2000]. Hence, the soil-plant-animals system is a complex system which has not been investigated adequately. Therefore, information is required on interrelationships of minerals among soil, plant and animals.

Soil is the source of all mineral elements found in plants and most naturally occurring minerals deficiencies in livestock are associated with specific season and are directly related to both soil minerals concentration and soil characteristics and of all the mineral concentration in soils only a fraction is taken up by plants. The bioavailability of minerals in soils depends upon their effective concentration in soil solution [Ried and Horvath, 1980]. The forages concentration of minerals depend on the interactions of a number of factors including soil, plant species, stage of maturity, yield, pasture management, climate and interactions among the minerals [McDowell, 1985; Rogers, 2003; Aregheore and Singh, 2003]. Mineral concenrtrations in both soils and herbage affect the mineral status of grazing livestocks [Towers and Clark, 1983], therefore the amount of minerals in forages and biological avaialabilty of minerals need to be considered in the formulation of rations for grazing livestocks [Aregheor and Hunter, 1999].

Heavy metal pollution is a major global problem posing serious risk to human, animals and the environment [Fernandez and Olalla, 2000]. Diverse amounts of heavy metals found everywhere in the soils, water, river sediment and plants even the Arctic region [Szefer, 1995; Pacyna, 1994]. Soils contain a wide range of heavy metals with varying concentration ranges depending on the surrounding geological environment, anthropogenic and natural activities [Dube et al., 2001]. The presence of heavy metals in water results from weathering of soils and rocks and with its products. In most developing countries including India, it is often attributed to industrialization with improper waste disposal and also by some heavy metal deposition from the parent materials. Impact of pollution on domestic and wild animals and on the environment due to chemical toxicities is reported. High levels of heavy metals in soil, water and animals have been reported in different part parts of India mainly due to pollution and in small measure by the parent material. Forage plants grown under polluted environment may absorb toxic metals from soil, irrigation water and metal deposits and may become the source of metal presence in the animal body. High amount of heavy metals are reported in serum samples of animals consuming the forages grown in contaminated land and irrigated with contaminated water. A higher occurrence of reproductive tract disorders (55.67%) is found in farms exposed to a metallurgical plant [Maracek et al., 1998] and are connected with functions of other organs, particularly liver [Kottferova, 1996].

Nominal to very limited work under the cold desert high altitude microclimate on major and trace mineral nutrients interrelationships among soil, forages and animals and heavy metals status and their exposure in water, soil, plant and animal systems. Thus the present work is designed in the present view that will help to formulate the region specific mineral mixtures and animal health managements for toxic effects of heavy metals due to their high intake with feeds and water at high altitude cold arid environment. The present study was conducted with the following objectives:

- To know certain essential minerals status in soil, fodders, water and blood of sheep and goat at high altitude cold arid environment.
- To know certain essential minerals interrelationships in soil, fodders and native sheep and goat at high altitude cold arid environment.
- To evaluate heavy metal presence in soil, fodders, water and blood of native sheep and goat at high altitude cold arid environment.

# CHAPTER II

## To know altitudinal variations in soil physico-chemical properties of cold desert high altitude

## Abstract

The extreme nature of climate and topographical conditions may affect soil properties at cold desert high altitude. Hence, the present investigation was undertaken to know altitudinal variations in soil physico-chemical properties at cold desert high altitude region. For this, agriculture soils were collected from different altitude viz. site I (10000-11000 ft.amsl), site II (>11000-12000 ft.amsl) and site III (>12000 ft.amsl) at Leh-Ladakh (cold desert high altitude region), India. Interestingly, sand percentage in soil was significantly ($P<0.05$) high at site III and increased gradually with altitude. In contrast to sand level, silt concentration was high at site I and decreased significantly ($P<0.05$) with increasing altitude. There was no significant ($P<0.05$) difference in bulk density (BD) and electrical conductivity (EC) among all study sites. However, the higher values of pH, total dissolved solid (TDS) and $CaCO_3$ were recorded at site I while higher soil organic matter (SOM) was at site III. Pearson correlation coefficient ($r^2$) analysis showed the negative correlation ($P<0.01$, $P<0.05$) of clay, silt and pH, whereas positive correlation of sand and SOM ($P<0.01$) with altitude. Hence, our findings suggested the altitudinal variations in soil physico-chemical properties at cold desert high altitude.

**Keywords:** Altitudinal variation, Cold desert, High altitude, Physico-chemical properties, Soil.

## 2.1 Introduction

Over the past decades, high altitude soils have attracted more attention in the debate on the potential impact of environmental changes on the global carbon cycle [Li et al., 1998; Oechel et al., 2000; Zeglin et al., 2009]. Recently, increased pressure on agriculture sector to produce more grains and fodder in cold desert high altitude region has raised the concern on soil health and their management practices [Sharma et al., 2006]. Soils at cold desert high altitude are coarse textured, permeable and arid, have poor water and nutrient holding capacity so have low nutrient availability for growing crops which perform differently in different soil types [Jobbagy and Jackson, 2000; Dwivedi et al., 2005; Sharma et al., 2006]. The soils of Leh-Ladakh i.e. cold desert high altitude region are poor in mineral nutrients, wind erosion occurs on a mammoth scale and paucity of water is a perennial blockage [Bowman et al., 2002; Ladakh Autonomous Hill Development Council, 2005; Sharma et al., 2006]. Also, soil micro flora population is sparse due to poor soil structure, texture, very high sand and clay, low biological activity and freezing during long winter period in this region [Campbell and Claridge, 1987]. The extremely high altitude of Himalaya probably provides a unique glacial climate on earth. In this area, sub zero temperature during maximum periods are responsible for different texture, mineralogy and very low soil development process indicating more advance stage of weathering. Altitude profoundly affects the soil's inherent fertility and runoff-erosion behavior [Mani, 1990; Bowman et al., 2002]. Level of rainfall, snowfall and temperature variation affects organic matter decomposition that causes increased accumulation of organic matter with elevation [Walker et al., 2000]. These changes in microenvironment may affect physico-chemical characteristics of soils in this region hence there is need to study the physico-chemical characteristics of soils in this area. Many soil fertility characteristics (including organic matter content, pH, cation exchange capacity, phosphorus absorption and their availability) show significant altitudinal variations [Jobbagy and Jackson, 2000]. Since, crop production and soil managements differ with the type of soil and their physico-chemical behavior [Mani, 1990; Sharma et al., 2006]. Therefore, in such fragile agro ecosystem soils need to be handled carefully for stabilized and sustainable crop production. Keeping the above circumstances and problems, the present study was designed to know the physico-chemical characteristics of agricultural soils along the altitude gradients in cold desert high altitude region of Leh-Ladakh.

## 2.2 Material and methods

### 2.2.1 Survey of study site

The study area lying in Leh-Ladakh (10000 to 13060 ft. amsl, 33°59.362 to 34°17.722 N latitude and 077°12.023 to 077°45.669 E longitudes) which is situated in Eastern Ladakh Plateau a part of Tibetan Plateau (Fig 2.1). This comes under cold desert high altitude region and surrounded by the Indus and Zanskar Rivers under the rain shadow of the Himalayas. Annual precipitation is <100 mm mostly in form of snow. The higher northern part of the Ladakh plateau remains under permanent snow cover. Temperature ranges from -40$^{0}$C to +40$^{0}$C and average relative humidity range is 24.70 and 39.03% (Table 2.1). The area dominantly represented by Ladakh series is classified as Typic Cryorthent [Mandal et al., 1999]. High altitude causes reduced air density, vapor pressure, increased solar radiation, lower temperatures, increased wind velocity and high evaporation. Diversion of glacial fed rivers into stone built terraces and soil gathering through sedimentation enriches the soil with organic matter. Outflow of cold from the Himalayas produces a steeper temperature gradient due to their extreme high altitude. Interestingly, here growing time of crops varies considerably with altitude and decreases with the altitude.

**Table 2.1:** Climatic data (for the year 2008-09) of studied area

| Month | Temperature ($^0$C) | | | | Relative Humidity (%) | | | |
|---|---|---|---|---|---|---|---|---|
| | 2008 | | 2009 | | 2008 | | 2009 | |
| | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. |
| January | -15.21 | -3.95 | -13.92 | 0.40 | 35.39 | 48.29 | 27.42 | 39.97 |
| February | -16.21 | -2.81 | -10.89 | 3.98 | 29.10 | 47.93 | 23.50 | 36.75 |
| March | -6.31 | 9.44 | -6.90 | 8.45 | 27.61 | 41.23 | 21.71 | 33.06 |
| April | -1.66 | 13.42 | -2.07 | 13.78 | 27.30 | 45.57 | 21.40 | 30.50 |
| May | 2.61 | 18.18 | 1.98 | 17.82 | 27.58 | 52.23 | 21.77 | 28.94 |
| June | 10.96 | 26.22 | 5.24 | 21.15 | 22.63 | 33.70 | 26.70 | 28.17 |
| July | 12.34 | 27.31 | 10.97 | 24.62 | 22.90 | 39.16 | 21.13 | 37.00 |
| August | 9.82 | 25.40 | 14.16 | 26.55 | 25.39 | 51.87 | 20.06 | 29.13 |
| September | 3.77 | 17.80 | 6.67 | 21.08 | 27.30 | 45.93 | 21.53 | 35.57 |
| October | -2.41 | 15.03 | -0.57 | 13.85 | 26.26 | 41.55 | 21.33 | 38.97 |
| November | -8.62 | 11.03 | -10.03 | 4.07 | 21.03 | 33.40 | 29.07 | 47.40 |
| December | -11.64 | 5.95 | -17.78 | 2.45 | 22.55 | 37.16 | 24.65 | 32.46 |

### 2.2.2 Soil sampling and processing

Total one hundred fourteen composite agriculture soil samples (Site I: 38, Site II: 38 and Site III: 38 sample) were collected from different altitudes and locations of the sampling sites were recorded by GPS (global positioning system) coordinated in the center. Random soil sampling was preferred due to very small size of plots present in this region. Ten sampling points were selected at each sampling sites, samples were collected from up to 15 cm soil depth (plough layer) and the required amount of soil sample was taken by quartering method. Root part and other plant residues were removed from the soil and then these soil samples were air dried at room temperature, sieved with <2.0mm test sieve. For analysis of soil organic carbon (SOC) and calcium carbonate, soil samples were further sieved with 0.2 mm test sieve. The pH, EC, TDS, clay, sand and silt were determined with 2.0 mm test sieved soil samples. For the bulk density (BD) determination, soil samples were collected at the same time and at same sampling sites using standard bulk density measuring container (100cm$^3$ in volume, 50.46mm in diameter and

50 mm in height, Model NL 0303, Beijing New Landmark Soil Equipment Co. Ltd. Beijing China Mainland) and thereafter, samples were oven dried at $105^{0}$C for 24 hours.

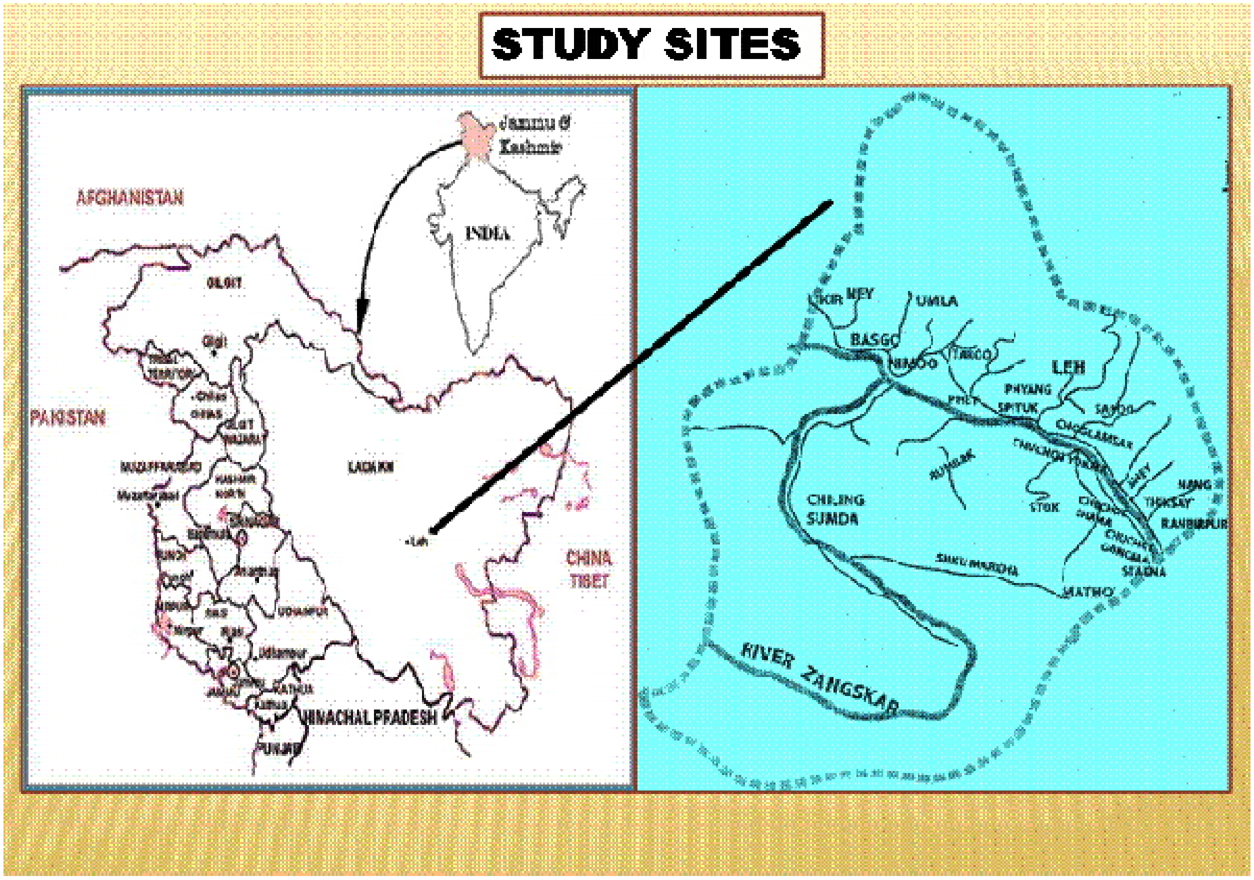


**Figure 2.1:** Map of study area

### 2.2.3 Analysis of physico-chemical parameters

Chemical and reagents used were GR grade, purchased from Merck, Germany. Soil organic carbon (SOC) was analyzed by wet digestion method [Walkley and Black, 1934]. The organic matter content (OMC) was calculated by multiplying SOC content with Van Bemmelen factor (1.724). Total calcium carbonate content was estimated by Back titration method [Bashour and Sayegh, 2007] and pH, EC and TDS were measured as described by Tandon [1993] by preparing (1:2) soil and water solution for one hour in a rotary shaker. However, silt, sand and clay proportions were determined by bouyoucos hydrometer method.

### 2.2.4 Statistical analysis

All the data collected in this study were analyzed for mean and standard error (SE) by one way ANOVA using the SPSS computer programme (17.0 versions). Significance level ($P<0.05$) was generated among the different mean values by Duncan's multiple range test

(DMRT) among different sampling locations. Pearson correlation coefficient ($r^2$) analysis was done among the soil, plant and animals for the various trace mineral elements using the computer program SPSS statistical software 17.0 versions for Windows.

## 2.3 Result

### 2.3.1 Clay, Sand and Silt proportions

The present study revealed no variation in clay (%) content, whereas sand content (%) was significantly ($P<0.05$) increased with the altitude (Table 2.2). However, silt content (%) showed reversed trend, as it decreased significantly ($P<0.05$) with the altitude (Table 2.2). Based on sand, silt and clay content, textural class of agricultural soil comes under sandy loam at different altitude (Table 2.2). The co-relation analysis revealed that clay (%) and silt (%) are significantly ($P<0.05$, $P<0.01$) negatively correlated with the altitude, whereas sand (%) was positively correlated with the altitude (Table 2.3). Co-relation analysis of silt (%) and silt+clay (%) showed negative correlation with SOM; however sand content (%) was positively correlated with SOM (Table 2.4; Fig 2.2, 2.3, 2.4, 2.5).

**Table 2.2:** Altitudinal variations in physico-chemical properties of cold desert agriculture soil

| Parameters | Study sites | | |
|---|---|---|---|
| | Site I (10000-11000 ft. amsl) | Site II (>11000-12000 ft. amsl) | Site III(>12000 ft. amsl) |
| Clay (%) | 12.53 $^{a}$±0.32 | 11.41 $^{a}$ ±0.62 | 10.96 $^{a}$ ±0.76 |
| Sand (%) | 52.40 $^{a}$ ±1.20 | 63.21 $^{b}$±1.97 | 69.99 $^{c}$±2.10 |
| Silt (%) | 35.08 $^{c}$±1.05 | 25.38 $^{b}$±1.77 | 19.04 $^{a}$±1.54 |
| BD ($g/cm^3$) | 1.38 $^{a}$±0.01 | 1.44 $^{a}$±0.02 | 1.43 $^{a}$±0.03 |
| SOM (%) | 1.42 $^{a}$±0.09 | 1.62 $^{a}$ ±0.08 | 2.45 $^{b}$ ±0.19 |
| $CaCO_3$ (%) | 6.26 $^{b}$±0.07 | 6.60 $^{b}$±1.50 | 3.24 $^{a}$±0.30 |
| EC (µs/cm) | 331.07 $^{a}$±52.58 | 294.72 $^{a}$±21.85 | 273.88 $^{a}$±18.22 |
| pH | 8.44 $^{b}$±0.04 | 8.21 $^{a}$±0.04 | 8.25 $^{a}$±0.07 |
| TDS (ppm) | 160.35 $^{b}$±12.12 | 142.05 $^{a}$±10.72 | 131.82 $^{a}$±8.89 |
| Textural class | Sandy loam | Sandy loam | Sandy loam |

Values (Mean ±SE) bearing different superscript ($^{a,b,c}$) in a same row differ significantly ($P<0.05$)

### 2.3.2 BD, SOM and Calcium carbonate

The values of BD (g/cm$^3$) did not shown any significant ($P<0.05$) difference in all study sites, although the SOM content was reported significantly ($P<0.05$) higher at the highest altitudinal site (site III) as compared to site I and II (Table 2.2). On the other hand the $CaCO_3$ content (%) was significantly ($P<0.05$) higher at site I and II (lower altitude site) as compared to site III (Table 2.2). Pearson correlation coefficient ($r^2$) analysis revealed that the SOM content (%) was significantly ($P<0.01$) positively while $CaCO_3$ (%) significantly ($P<0.05$) negatively correlated with altitude in the present study (Table 2.3).

**Table 2.3:** Correlation analysis of physical properties with altitude of cold desert agriculture soil

| | Clay (%) | Sand (%) | Silt (%) | BD (g/cm$^3$) | $CaCO_3$ (%) | SOM (%) |
|---|---|---|---|---|---|---|
| Pearson Correlation Coefficient ($r^2$) | -0.179 (*) | 0.408 (**) | -0.413 (**) | 0.114 | -0.158 | 0.391 (**) |
| Sig. | 0.041 | 0.000 | 0.000 | 0.197 | 0.073 | 0.000 |

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

**Table 2.4:** Correlation of soil organic matter (SOM) content (%) with sand, silt, clay and silt + clay (%) of cold desert agriculture soil

| | Sand (%) | Silt (%) | Clay (%) | Silt + Clay (%) |
|---|---|---|---|---|
| Pearson Correlation Coefficient ($r^2$) | 0.451** | -0.492** | -0.066 | -0.451** |
| Sig. | .000 | .000 | .523 | 0.000 |

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

**Table 2.5:** Correlation analysis of chemical properties with altitude of cold desert agriculture soil

| | pH | EC (µS/cm) | TDS (mg/l) |
|---|---|---|---|
| Pearson Correlation Coefficient($r^2$) | -0.190 (*) | -0.056 | -0.054 |
| Sig. | 0.031 | 0.529 | 0.544 |

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

### 3.3.3 pH, EC (µS/cm) and TDS (ppm)

The significantly ($P<0.05$) higher pH and TDS values were reported at site I (10000-11000 ft. amsl) and lower at site II (>11000-12000 ft. amsl) and site III (Table 2.2). pH was significantly (P<0.05) negatively correlated with altitude (Table 2.2 & 2.4). However, the higher value of EC (µS/cm) was reported at site I and lower value at site III respectively, but there was no significant (P<0.05) difference observed in all studied sites (Table 2.2 & 2.4).

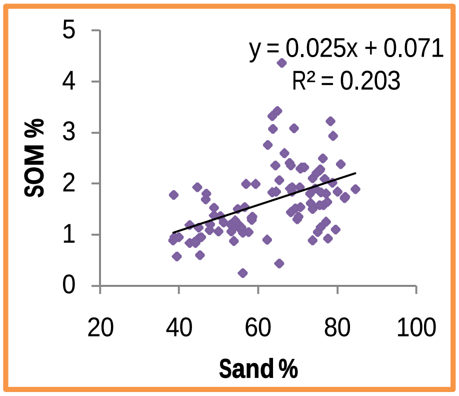


**Fig 2.2:** Correlation between SOM and sand contents

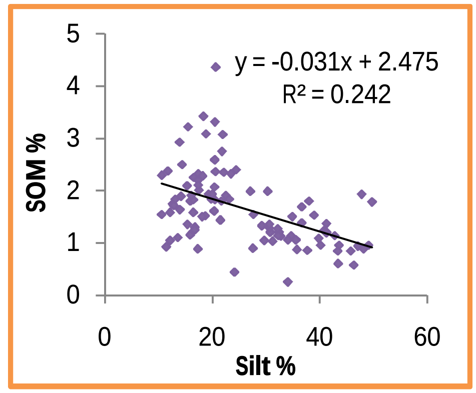


**Fig 2.3:** Correlation between SOM and silt contents

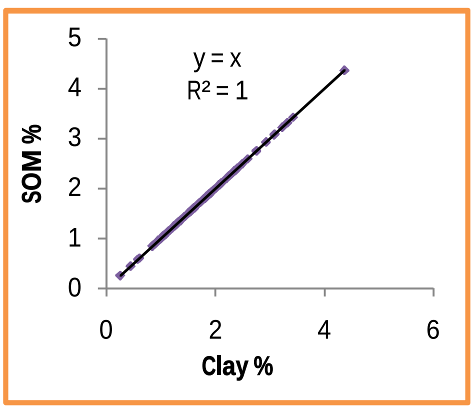


**Fig 2.4:** Correlation between SOM and clay contents

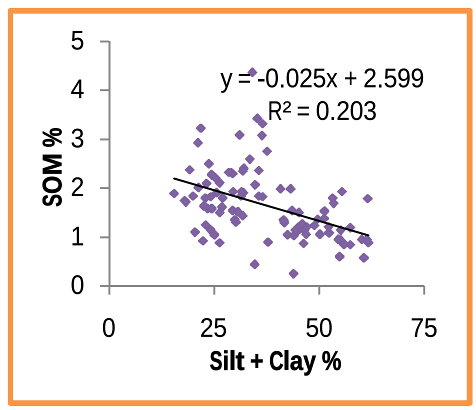


**Fig 2.5:** Correlation between SOM and Silt + Clay contents

## 2.4 Discussion

### 2.4.1 Clay, Sand and Silt proportions

Soils of cold desert high altitude have originated from weathered rocks, are immature, with large proportion of sand gravel and stones [Brady and Weil, 1999]. In present study, sand fraction found increasing significantly (P<0.05) along the altitude and silt in reverse order of sand denoting the dominance of sand forming minerals in parent materials this may be due to the slow processes of soil mineralization and soil formation. Hence, our findings indicated that the cold arid soils are dominated by sand like the hot arid soils and the relatively high proportion of sand in these soil fragments causes sandy loam textural class in this region. Schinner [1982] and Brady and Weil [1999] propound that the nature and parent material profoundly influence the soil characteristics. 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, availability and movement of water along the altitude). Higher silt but lower sand proportion observed at lower altitude in our study that indicates the presence of quartz, feldspars, hornblende and micas in the soil [Brady and Weil, 1999]. It is also assumed that the lack of smaller size particles shows the slow process of weathering in this region [Brady and Weil, 1999]. Therefore, slow process of soil formation along the altitude results in very low content of clay particles which may cause low content of available mineral nutrients in this soil [Brady and Weil, 1999].

### 2.4.2 BD, SOM and Calcium carbonate

In present study, the bulk density (BD) was determined along the altitudinal gradient shown no significant changes and seemed at par. It was reported that the bulk density is related to natural soil characteristics like texture, organic matter, soil structure [Chen et al., 1998] and varies due to action of several processes like freezing and thawing [Unger 1991]. Among the soils of different textures, structures and soil organic matter content and further changes in BD affect other properties and processes that influence water, oxygen supply in the soil. The SOM content (%) was increasing with altitude in this investigation. These findings got support of Garten et al. [1999] and Bolstad and Vose [2001] studies, who also reported increasing soil carbon concentration with altitude in mountainous terrain. Sims and Nielsen [1986] also observed the positive correlation between SOM and altitude. Temperature is the main climatic variable which control SOM at cold desert. Bhattacharyya et al. [2008] reported lower atmospheric temperature at subzero level, causes hyper aridity at cold desert high altitude which further does not support growth of vegetation. Therefore, this might be the reason that cold arid bioclimate of Ladakh contains more SOM. Since, low temperature decreases SOM decomposition and provides longer residence time. Trumbore et al. [1996] also revealed that, the turnover time of soil carbon increased with elevation or due to decline in mean annual temperature (MAT). Hence, increasing trends of SOM content (%) with increasing altitude may be due to the constant carbon inputs and decrease rate of carbon loss in present study.

Glenn et al. [1992] reported that the dry land soils are less likely to lose carbon than the wet soils, as the lack of water limits soil mineralization and therefore the flux of carbon to the atmosphere also get lowered; as a result the residence time of carbon in the dry land soils is comparatively longer. Therefore, higher precipitation in the form of snow at higher altitude than the lower altitude and subzero temperature causes suppression of microbial and enzymatic activities, that results in least or nil SOM decomposition during winter and spring that further make higher accumulation of SOC [Schinner, 1982; Jacot et al., 2000]. Soil respiration is one of the major factors of SOM loss but at this region soil respiration is very low in winter and spring season in higher altitude sites which results in low SOM decomposition rate. These findings are in agreement with Chambers [1998] who also reported low soil respiration and carbon loss in the Great Smoky Mountains National Park with increasing altitude. Soil texture, determined by the relative proportion of clay, silt and sand are the important regulator of soil respiration and decomposition in most environments, which controls SOM accumulation and mineral nutrients [Jenny, 1980; Schimel et al., 1985]. Water movement and its availability in cold desert is the major limitation due to sub zero temperature during winter and spring that influences soil weathering and mineralization which also affect SOM accumulation [Chapin et al., 1995; Grogan and Chapin, 2000; Shaw and Harte, 2001; Barrett et al., 2008].

Cold desert vegetations have higher root: shoot ratios, shallower root distributions and above ground litter fall and root mortality are the two primary processes that contribute to soil carbon inputs along the elevation gradient [Jackson et al., 1996; Yang et al., 2009]. Cold desert high altitude region is known by its longer photoperiod with high light intensity (>12 hrs), it is one of the important factor controlling carbon sequestration in soil at this cold desert high altitude region as it induces comparatively higher carbon synthesis and assimilation in plant and plant products rather than lower altitudes that results in higher input of SOC is soil [Charan et al., 2012]. Decreasing trend in $CaCO_3$ concentration (%) with increasing altitude in our study may be due to the climatic factors viz. low temperature, low respiration rate and high precipitation along the altitude and type of the parent materials (calcite mineral in soil profiles). Since, temperature affects $CaCO_3$ equilibrium directly through its influence on the solubility constant and indirectly through its effect on the partition of precipitation inputs between evapotranspiration and leaching [Feng et al., 2002]. It is assumed that $CaCO_3$ content at lower altitude, site I and site II (>10000-12000 ft. amsl) remain uniform in high concentration as compared to higher altitude (>12000 ft. amsl, site III) in low concentration with special reference to cold desert of Ladakh region. Feng et al. [2002] reported that the soil inorganic carbon content showed a stronger positive correlation with evaporation and negative correlation with temperature and precipitation, which are the characteristics of this cold desert cold high altitude micro-environment. Decrease of water content or partial pressure of $CO_2$ or increase of $Ca^{2+}$ or $HCO^{-}_3$ concentrations can lead to a favorable environment for the precipitation of pedogenic form of inorganic carbon [Wilding et al., 1990]. Therefore, lower altitudes of Ladakh have comparatively higher evaporation rate of soil and high soil mineralization, which may result in higher accumulation of $CaCO_3$ as compared to higher altitudes. Availability of water is also an important factor in $CaCO_3$ accumulation [Nordt et al., 2000]. Studied area in present investigation has marked depletion of water. Pedogenic form of inorganic carbon accumulation in arid and semiarid soils occurs because of water deficit (evapotranspiration>precipitation) constraint significant leaching that helps pedogenic inorganic carbon accumulation [Nordt et al., 2000].

### 2.4.3 EC, pH and TDS

We did not found any significant differences in EC, so this finding indicated that there is no major difference in cumulative salt accumulation along the altitudes. However, decreasing trend of pH and TDS from lower altitude (10000-11000 ft. amsl) to higher altitude showed the lower altitude sites have more cumulative salt accumulation rather than higher altitude sites. This may be due to the higher accumulation of base forming cations like $Ca^{+2}$, $Mg^{+2}$, $K^{+}$ and higher accumulation of $CaCO_3$ [Northcott et al., 2009]. We also observed <6.0 % $CaCO_3$ at >12000 ft. amsl, this finding confirms that this cold desert high altitude soil is calcareous in nature. Hence, our study indicated that cold desert soils are typically alkaline with broad ranges of salinity reflecting surface exposure age and local hydrological conditions [Northcott et al. 2009]. Since, calcareous soils occur naturally in arid and semi-arid regions because of relatively little leaching [Brady and Weil, 1999]. It is presumed that calcareous soils of this cold desert high altitude may be developed by predominantly available calcareous parent material (calcite mineral) throughout the soil profiles.

## 2.5 Conclusion

These results revealed that the agriculture soil at cold desert high altitude region is calcareous in nature with alkaline reaction. The relative proportion of soil fragments forming coarse grained texture in increasing order along the altitudes, constituted the sandy loam textural class. Sand fragment and SOM concentrations are positive correlated, while the pH, clay and silt contents are negatively correlated with special reference to cold desert high altitude region. Hence, our findings predicted the altitudinal variations in physico-chemical characteristics of agricultural soil at cold desert high altitude. Therefore, this study will open further scope for Researchers to look into the new soil management approaches and cultivation practices along the altitude gradients of this cold desert high altitude region.

# CHAPTER III

## To know altitudinal variations in soil carbon storage and distribution patterns in cold desert high altitude region of India

**Abstract**

A study was conducted to assess the soil carbon distribution in cold desert high altitude region of Ladakh in India at different altitudes and their correlation patterns with the altitude. The role of carbon dynamics in the exchange of $CO_2$ between the terrestrial biosphere and the atmosphere has important implications in this study of global climate change. The present study was done in Ladakh region of India from where soil samples were collected on the basis of different altitude ranges and thereafter samples were analyzed for organic carbon and calcium carbonate content. Results of our study shown that, the soil organic carbon (SOC) content and storage increased significantly with the increase in the altitude whereas soil inorganic carbon (SIC) content and its storage decreased significantly ($P<0.05$) with altitude. The SOC content and storage were observed significantly ($P<0.01$) positively correlated with altitude, while soil inorganic carbon storage and contents were negatively ($P<0.05$) correlated with altitude. Hence, our study indicated that, very harsh and unique climatic conditions in Ladakh influences storage and distribution pattern of soil carbon along the altitudes or elevation gradients. So investigations along altitude gradients is a useful approach to the study of environmental change and its effect on the soil processes, which can complement data obtained from controlled, large scale field studies as well as other practical and theoretical approaches to climate change research.

**Key words:** Cold desert, high altitude, carbon distribution pattern, altitudinal variation, soil carbon, microclimate.

## 3.1 Introduction

Soil is the largest carbon reservoir pool of terrestrial ecosystem and plays a key role in the global carbon budget and greenhouse effect [Jha et al., 2003]. It contains 3.5% of the earth's carbon reserve as compared with 1.7% in the atmosphere, 8.9% in fossil fuels, 1.0% in biota and 84.9% in the oceans [Lal et al., 1995]. Soil reserve about 1550 gT of carbon as soil organic carbon (SOC) and 1700 gT as carbonate carbon (soil inorganic carbon, that is, SIC). Soil carbon (C) balance plays an important role in exchange of $CO_2$ between atmosphere and biosphere. Hence, even a minor change in SOC storage could result in a significant alteration in atmospheric $CO_2$ concentration [Davidson and Janssens, 2006; Schipper et al., 2007]. SOC and SIC are important as they determine ecosystem and agro ecosystem functions influencing soil fertility, water holding capacity and other soil characteristics. Therefore, the accurate estimation of SOC storage and its distribution is critical for predicting feedbacks of soil carbon to global environmental change [Callesen et al., 2003; Wynn et al., 2006]. The Himalayan region (western and eastern zones) constitutes 19% of total geographical area in India and contributes 33% SOC and 20% SIC stocks of the country. Western zone of Himalayan region in which cold desert Ladakh plateau comes, contribute 19% SIC stock of India while it covers 10% area of TGA [Bhattacharyya et al., 2008]. Ladakh, a cold desert high altitude area in India is situated at an altitude of 3000 to 5000 m. above mean sea level (amsl). Soils in high-altitude ecosystems play an important role in the global terrestrial carbon cycle because of their large carbon stock and potential sensitivity to climate warming [Zimov et al., 2006; Yang et al., 2008; Post et al., 2009]. The changes in climate along the altitudinal gradient influence the composition and productivity of vegetation, consequently affect the quantity and turnover of soil organic matter (SOM) [Garten et al., 1999; Quideau et al., 2001] and also influences SOM by controlling soil water balance, soil erosion and geologic deposition processes [Tan et al., 2004]. However, the storage and spatial patterns of SOC in high-altitude ecosystems remain largely uncertain, due to insufficient field observations and large spatial heterogeneity [Garnett et al., 2001; Liu et al., 2006; Yang et al., 2007]. Measuring the quantity and spatial distribution of SOC is essential for evaluating soil function and understanding soil carbon sequestration processes [Venteris et al., 2004; Wei et al., 2006]. But little is known about storage and distributions of SOC and SIC along the altitude gradients in cold desert high altitude ecosystems. Thus direct observations from high-altitude ecosystems are urgently needed to improve our understanding of biogeochemical cycles for cold desert high altitude regions and their potential feedbacks to global environmental change. Present experiment thus has been planned with the objective to assess the altitudinal variations in storage and distribution of soil carbon in Ladakh.

## 3.2 Material and Methods

### 3.2.1 Survey of study site

This present study was conducted on soil samples collected from Leh district of Ladakh in India (Latitude, 32° 15’-36° N; Longitude, 75° 15’-80° 15’ E and an altitude above 3500 m. amsl) and sampling of study area is shown in Figure 3.1. Ecologically Ladakh region in Tibetan Plateau is a high altitude cold desert under the rain shadow of the Himalayas. Since the region lies in the rain shadow it is one of the driest places on the earth. Geographically, Ladakh is one of the divisions of Jammu and Kashmir province in India, divided into two districts namely Kargil and Leh. Leh is situated in the eastern Ladakh Plateau and come under cold hyper arid ecosystem (ESR) surrounded by the Indus and Zanskar Rivers. Leh district is situated between 32° to 36° N latitude and 75° to 80°E longitude and at an altitude ranging from 2900 to 5900 m amsl. This study area lies between 33°59.362 to 34°17'722 N latitude and 077°12'023 to 077°45'669 E longitudes and with at an elevation ranging from 10526 ± 32.30 to 13063 ± 20.20 ft. amsl. Annual temperature in this region ranges from -30 to +40°C and annual minimum and maximum average temperature is -1.46°C and +13.48°C, respectively. Annual minimum and maximum average relative humidity is 24.70 and 39.03%, respectively. Annual precipitation is less than 100 mm mostly in form of snowfall and as the climatic data of this study area is presented in Table 2.1. Due to high altitude and low humidity, the radiation level is amongst the highest in the world (up to 6-7 Kwh/mm). Longer photoperiod (<12 hour) and about 330 sunny days and only one cropping season in a year (span from May to October) are typical characteristics of this region. Nevertheless, by diverting glacial fed rivers into stone built terraces, gathering soil through sedimentation, enriching the soil with organic manure and other practices, local farmers are able to cultivate staples under such harsh climatic conditions in this region. Major crops grown on agriculture fields are *Triticum aestivum* L., *Hardeum vulgare* L. and *Medicago sativa* L. Waste lands are covered by thorny shrub, *Hippophea rhamnoids* L. Forest around agriculture fields and glacier Valleys are covered by *Salix spp.* (Willow) and *Populus spp.* (poplar). Grasslands were spread with *Carex melanantha* L. and *Agropyron repens* L. as major grass species. Soil of Ladakh is taxonomically classified as typic cryorthids, physically thin, porous, with low water holding capacity and sandy in nature, which may be because of more quantity of stone and gravels content in dry mountains of this region.

### 3.2.2 Soil sampling and processing

This study area was situated in Leh district of Ladakh. Three sites were selected on the basis of altitudinal gradients, site-I (10,000- 11,000 ft. amsl), site-II (>11,001-12,000 ft. amsl) and site-III (>12,000 ft. amsl). Soil samples were collected from the agriculture soil and altitude of sampling sites were recorded by putting the GPS (global positioning system), a site locator instrument in the centre of sampling plot. For soil sampling, a plot of 100 × 20 m size was laid and six sampling points were selected and one small sample was collected at each sampling point at the depths of 15 cm (plough layer). A total of 75 soil samples (25 from each altitudinal site) were collected. All soil samples were air dried at room temperature, sieved with <2.0 mm test sieve. Litter, root parts and other plant residues were removed from the soil. For analysis of soil organic carbon and calcium carbonate, soil samples were again sieved with 0.2 mm test sieve. For the bulk density determination, soil samples were collected at the same time and from same sampling sites using a standard container with 100 $cm^3$ in volume and oven dried at 105°C for 24 hours.

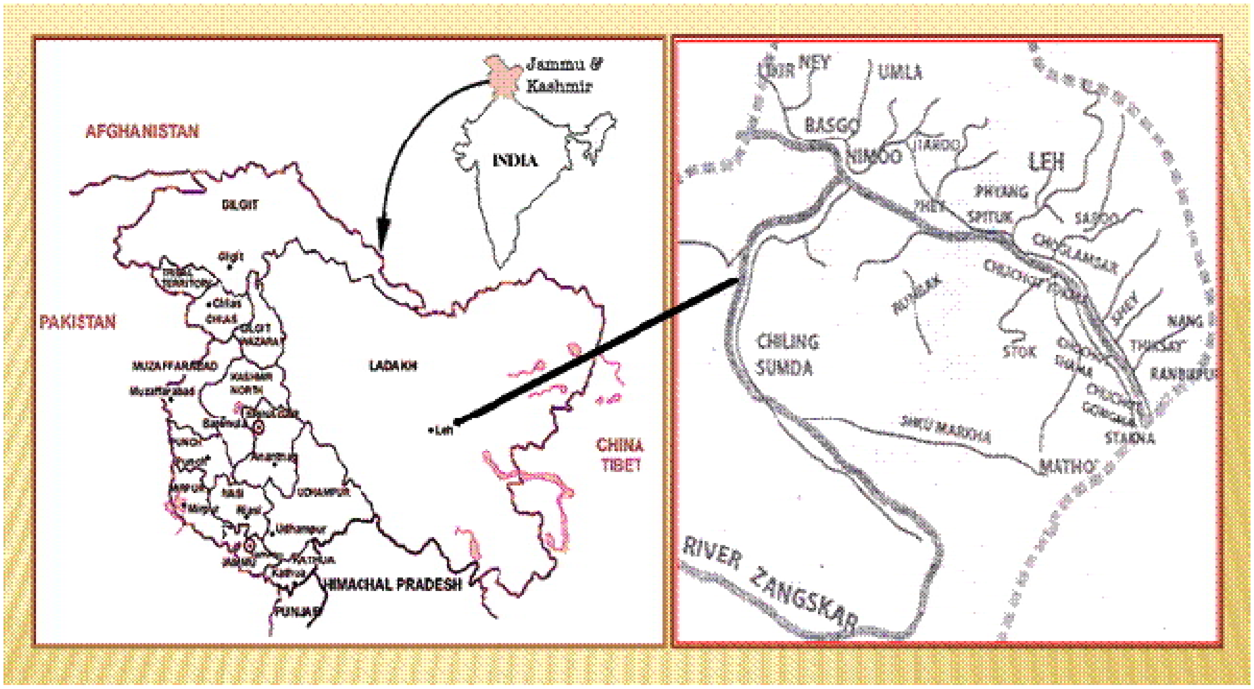


**Figure 3.1: Map of study site**

### 3.2.3 Analysis of soil sample

Chemicals used in the analysis of soil organic carbon and calcium carbonate were GR grade, purchased from Merck, Germany. Soil organic carbon was analyzed with wet digestion method [Walkley and Black, 1934]. In this study, the term carbonates refer to the sum of $CaCO_3$, $MgCO_3$ or other carbonate minerals in soils, of which $CaCO_3$ is dominant and dolomite [$CaMg(CO_3)_2$] and $MgCO_3$ are usually minor components [Doner and Lynn, 1977]. A factor of 0.12, the mole fraction of carbon in $CaCO_3$, was used to convert calcium carbonate to SIC content. The SOC and SIC content in the soil were converted to total SOC and SIC storage [Kukal et al., 2009]. Total SOC or SIC storage = % SOC or SIC/100 x (BD x 1500). Where: Total SOC or SIC storage in t/ha; SOC or SIC is soil organic and inorganic carbon (%); BD is soil bulk density of 0–15 of soil depth ($Mg/m^3$); 1500 is the volume of 1.0 hectare furrow slice (0.15 m) ($m^3$)

### 3.2.4 Statistical analysis

Data generated in this study were analyzed for mean and standard error (SE). Significance level was generated among the different altitude range by one way ANOVA using SPSS statistical software (SPSS Inc., 1999). Pearson correlation coefficient ($r^2$) was done for the analysis of correlation among the studied parameters

## 3.3 Results

### 3.3.1 SOC and SIC content (%)

SOC contents (%) from site-I to site-III, were found in increasing order (P<0.05) with the altitude (Table 3.1). The maximum SIC content (%) was reported at site-I which was significantly (P<0.05) higher than site II and III. There was no significant (P<0.05) difference observed in SIC content between site-II and site-III.

**Table 3.1:** Soil organic and inorganic carbon contents at different altitudes in agricultural soil

| Altitude range (ft.amsl) | SOC (%) | SIC (%) |
|---|---|---|
| 10000-11000 | $0.81^{a}$ 0.04 | $0.96^{b}$ ±0.21 |
| >11000-12000 | $1.00^{b}$ ±0.05 | $0.31^{a}$ ±0.03 |
| >12000 | $1.32^{c}$ ±0.09 | $0.38^{a}$ ±0.04 |

Values (N=25; Means ±SE) in the same column bearing different superscripts ($^{a, b, c}$) vary significantly (P<0.05).

### 3.3.2 SOC and SIC stock (t/h)

Statistical analysis (one way ANOVA) disclosed that the SOC stock from site-I to site-III was found increasing significantly (N=25, P<0.05), degree of freedom (between groups 2, within the group 72 and total 74) with increase in altitude range (Table 3.2). SIC stock was reported highest at site-I and found significantly (N=25, P<0.05), degree of freedom (between groups 2, within the group 72 and total 74) higher as compared to other sites. SIC stock at site-II and Site-III did not shown any significance difference among each other (Table 3.2).

**Table 3.2:** Soil organic and inorganic carbon stock at different altitudes in agricultural soil

| Altitude range (ft. amsl) | SOC(t/h) | SIC(t/h) |
|---|---|---|
| 10000-11000 | 16.74 $^{a}$ ±0.80 | 19.51$^{b}$ ±3.99 |
| >11000-12000 | 21.69 $^{b}$ ±1.08 | 6.82 $^{a}$ ±0.74 |
| >12000 | 28.83 $^{c}$ ±1.70 | 8.32 $^{a}$ ±0.84 |

Values (N=25; Means ±S.E) in the same column bearing different superscripts ($^{a, b, c}$) vary significantly (P<0.05).

### 3.3.3 Correlation between content and stock of SOC and SIC with altitude

From our present study in cold desert high altitude soil samples, Pearson correlation coefficient ($r^2$) study revealed that the SOC content (%) was positively significantly (P<0.0001) correlated with altitude (r =0.637) (Table 3.3; Figures 3.2 and 3.4). Same trend was seen in SOC stock which was significantly (P<0.0001) positively correlated with altitude ($r^2$ =0.694). On the other hand the SIC content (%) and stock (t/h) was found negatively significantly (P<0.018 and P<0.020, respectively) correlated with altitude ($r^2$ =0.273 and 0.269, respectively) (Table 3.3; Figures 3.3 and 3.5).

**Table 3.3:** Correlation analysis of carbon contents and their storage with altitude in agricultural soil

| | SOC (%) | SIC (%) | SOC (t/h) | SIC (t/h) |
|---|---|---|---|---|
| Pearson correlation coefficient ($r^2$) | .637(**) | -.273(*) | .694(**) | -.269(*) |
| Sig. | 0.000 | .018 | .000 | .020 |

****** Correlation is significant at the 0.01 level (2-tailed).

***** Correlation is significant at the 0.05 level (2-tailed).

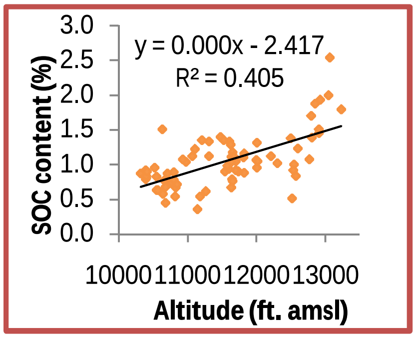


**Fig 3.2:** Correlation between altitude and SOC content in agricultural soil

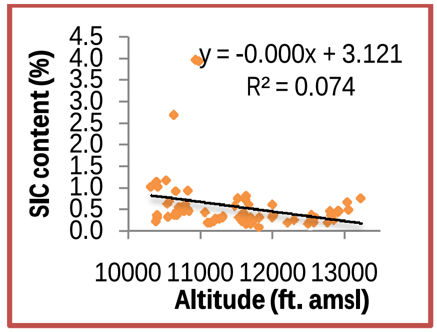


**Fig 3.3:** Correlation between altitude and SIC content in agricultural soil

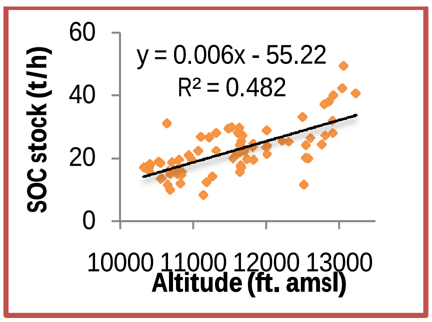


**Fig 3.4:** Correlation between altitude and SOC stock in agricultural soil

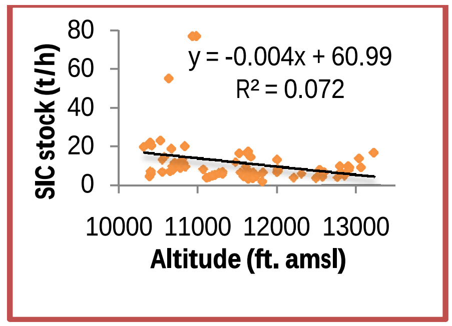


**Fig 3.5:** Correlation between altitude and SIC stock in agricultural soil

## 3.4 Discussion

SOC content and stock in agriculture soil of cold desert high altitude region of Ladakh in this present study showed interesting results as SOC content increased as altitude increased, while the same trends were reported in case of SOC stocks at all study sites of different altitudes. SOC in this present investigation is at higher side as compared to national average of soil organic carbon content of India. Bhattacharyya et al. [2008] reported that the lower atmospheric temperature at subzero levels causes hyper aridity which does not support vegetation growth and this may be the reason that cold arid microclimatic of Ladakh contain more content of SOC. Above ground litter fall and root mortality are the two primary processes that contribute to soil carbon inputs along elevation gradient. Jackson et al. [1996] and Yang et al. [2009] reported that the plants of high-altitude ecosystems have their own larger root: shoot ratios and shallower root distributions. This may result in to higher carbon concentration in the soil. Findings of this present investigation are in agreement with Chambers [1998] who reported that in the Great Smoky Mountains National Park, the soil respiration declines with increasing altitude leading to reduced loss of carbon. Other studies also indicated that the soil carbon concentrations or stocks increases with altitude in mountainous terrain [Townsend et al., 1995; Trumbore et al., 1996; Conant et al., 1998; Garten et al., 1999; Bolstad and Vose, 2001). Temperature is one of the dominant abiotic factor that affect carbon dynamics in cold desert high altitude ecosystems. Trumbore et al. [1996] found that the turnover time of soil C increased with elevation or declining mean annual temperatures (MAT). Here in cold desert high altitude region of Ladakh the MAT decreases with altitude due to higher mean annual precipitation (MAP) mostly in form of snow. Lower temperature decreases soil organic matter decomposition and provide longer residence time. Increasing trends of SOC content and stock with increase in altitude could also be due to constant carbon inputs and constant rate of carbon loss but reduced decomposition of organic matter due to lower soil temperature at higher altitude as compared to lower altitude. Glenn et al. [1992] reported that the dry land soil are less likely to lose carbon than the wet soils, as the lack of water limits soil mineralization and therefore the flux of carbon to the atmosphere also get lowered. As a result the residence time of carbon in the dry land soils is comparatively longer. The SIC content as well as storage in agriculture soil at cold desert high altitude region in Ladakh in our study decreased above the altitude of more than 11000 ft. amsl as SIC and stock at site-I (10000 to 11000 ft. amsl) was significantly higher as compared to both the sites II and III. These decreasing trends of SIC concentration and stocks may be due to some biotic and abiotic factors like, temperature, humidity, precipitation and type of the parent materials. Temperature is one of the most important abiotic variable which control SIC sequestration in cold desert high altitudes, as it affect $CaCO_3$ equilibrium directly through its influence on the solubility constant and indirectly through its effects on the partition of precipitation inputs between evapo-transpiration and leaching [Lal and Kimble, 2000; Feng et al., 2002]. It can be said that SIC and its storage above 11000 ft. amsl remain uniform and at lower concentration as compared to lower altitude with special reference to Ladakh region. Feng et al. [2002] reported that the SIC content showed a stronger positive correlation with evaporation and negative correlation with MAT (Mean Annual Temperate) and MAP (Mean Annual Precipitation). At lower altitudes in cold desert high altitude region of Ladakh, comparatively higher evaporation rate of soil due to high MAT, wind velocity and low MAP than the higher altitudes may result in higher accumulation of SIC as compared to higher altitudes. Decrease of water content or partial pressure of $CO_2$ or increase of $Ca^{2+}$ or $HCO^{-3}$ concentrations can lead to a favorable environment for the precipitation of pedogenic form of inorganic carbon [Wilding et al., 1990]. Availability of water is also an important factor in SIC accumulation. Studied area in this present experiment has marked depletion of water. Pedogenic form of inorganic carbon accumulation in arid and semiarid soils occurs because water deficit (evapotranspiration>precipitation) constrains significant leaching, favoring pedogenic inorganic carbon accumulation [Nordt et al., 2000]. The SOC content and storage increased with increasing altitude at all study sites. Thus it is apparent that the carbon distribution is positively correlated with altitude at cold desert high altitude in Ladakh. This may be due to the decrease in MAT, increased MAP, lesser litter decomposition, longer residence time for SOM, higher plant root: shoot ratio and shallower root distribution at higher altitude than the lower altitude. Sims and Nielsen [1986] reported that the SOM is positive correlated with altitude. An exactly opposite results were observed in case of SIC content and storage in the studied area.

## 3.5 Conclusion

There are no published reports on soil carbon distribution along the different altitudes in cold desert high altitude region of Ladakh in India as well as in other similar regions of the world. As per this study, SOC content and stocks in agriculture soil increases while SIC content and stocks decreases with increasing the altitude. Further, SOC concentration and storage are positively correlated, whereas SIC content and stocks are negatively correlated with altitude in cold desert high altitude region of Himalayan range. However further studies on the interrelationship of environmental variables like temperature, precipitation, N availability, litter chemistry and soil carbon storage pattern in such unique harsh climatic conditions of Ladakh and other similar regions in the globe needs to be further worked out for designing the policies related to global warming as well as for recommendations regarding soil management practices for improving agricultural productivity and sustainable development of population living in these regions.

# CHAPTER IV

## To know essential minerals status in pasture land, road side soil and river sediment of cold arid high-altitude region

**Abstract**

Essential mineral nutrients are the main constituents of soil ecosystems and status of soil directly affects the availability of these mineral nutrients to the feed/fodders and then to the livestocks. Therefore the present study was conducted with the objectives to investigate essential mineral nutrients in various soil ecosystems in cold arid region of India. The study was done in Leh-Ladakh which is a cold arid region of India and lies under the Tibetan plateau and it is the part of Trans-Himalayas. For the study, soil samples from various soil systems (pasture land, Indus river sediment and road side) were collected, six soil samples were collected from each sampling sites from studied soils, a total of 11 sampling site were selected for pasture and river sediments and 16 sites were selected for road side soil. All the soil samples were analyzed for iron, Magnesium, Manganese, Zinc and Boron. Our experimental results revealed that, Fe content varied from 9520 to 65660 mg/kg, whereas total mean concentration 32027.22±2026.57 mg/kg in pasture land. The total average content of Mn in pasture land, Indus river sediment and road side soils were found to 583.33±34.21, 661.28±118.77 and 582.99±20.71 mg/kg respectively, while they varied from 197.70-1089.00, 166-6603.00 and 300.30-1209.00 mg/kg respectively. The total mean concentration of Zn was reported to 84.87±7.91, 191.86±143.95 and 79.14±4.39 mg/kg respectively in pasture land, Indus river sediment and road side soils, while it ranged varied from 3.75-242.90, 17.48-7804.00 and 2.95-220.70 mg/kg respectively in pasture land, Indus river sediments and road side soils. B concentration ranged from 1.71-212.60, 2.24-5653.00 and 6.44-141.30 mg/kg and the total mean concentration was observed to 80.10±7.06, 151.62±103.89, 36.41±2.53 mg/kg respectively in pasture land, Indus river sediment and road side soils. Results of our study disclosed that the Fe, Mg, Mn, Zn and B were found within the typical range of soil and further they found above the critical deficiency level in all studied soils. Thus it indicates the levels of studied essential mineral nutrients are available in sufficient amount in the various soil ecosystems from cold arid region as the requirement of crop plants and livestock are concerned.

**Key words:** Essential mineral nutrients, Indus river sediment, soil ecosystems, cold arid, high altitude

## 4.1 Introduction

Soil presents the major repository of essential mineral nutrients, soil demonstrate an average composition close to the earth crust, but near the surface parent material from which soils are derived is not uniform. Soil forming processes differ markedly from one climatic region to another, accounting for considerable overall variability in trace metals concentration [Horton et al., 1977]. The natural concentration of essential mineral nutrients in soils is a result of weathering, which releases these mineral elements from their soil forming minerals during soil formation [Kabata-Pendias, 1993]. A close relationship between the metal content of the parent material and soils has been observed [Singh & Steinnes, 1994]. The mobility and solubility of mineral elements depend on the properties of minerals as well as the quality of soil, pH and other factors. Most of the major and trace elements (Fe, Mg, Mn, Zn, Cu, Co and B) are contributed through the weathering of igneous and sedimentary rocks in the soils. A number of these elements are biologically essential at trace levels present in natural water, air, dusts, soils and sediments and play an important role in human life [Mokhtar et al., 1991; Juvanovic et al., 1995].

The natural concentration of trace elements in soils is a result of weathering that releases trace elements from their host minerals during soil formation [Kabata-Pendias, 1993]. A close relationship between the metal content of the parent material and soils has been observed in a number of studies [Singh & Steinnes, 1994]. The mobility, solubility and bioaccumulation of trace elements depend on the properties of the trace elements as well as the quality of soil, pH and other factors. The bioavailability of trace and major elements in the soil is decisive for agriculture purposes. The speciation of major, trace minerals and heavy metals ultimately determines their bioavailability and their mobility in the soil [Pelfrene et al., 2009]. Most of the major and trace elements are contributed through the weathering of igneous and sedimentary rocks in the soils. There is no specific study in this region on the various soil systems that can reveal the essential mineral nutrients status and their distribution, by keeping this point in mind the present study was designed with objectives to assess the level of essential mineral nutrients and their distribution throughout the soil systems from cold arid microclimate of India.

## 4.2 Material and Methods

### 4.2.1 Survey of study site

The present study included various types of soil systems of this region viz. Indus river sediment, pasture land and road side soils. These soils scattered over a larger area of Indus Valley and particularly lie in Leh district of Ladakh division in India. Ecologically Ladakh region lays in Tibetan Plateau is a cold arid region under the rain shadow of the Himalayas. Since the region lies in the rain shadow it became one of the cold driest (cold arid) place on the earth. Leh is situated in the eastern Ladakh Plateau and come under cold hyper arid ecosystem (ESR) surrounded by the Indus and Zanskar Rivers. Leh district is situated between $32^0$ to $36^0$N latitude and $75^0$ to $80^0$E longitude and at an altitude ranging from 3500 to 6500 m. amsl. The study area lies between 33°59'362 to 34°17'722 N latitude and 077°12'023 to 077°45'669 E longitude and with at an elevation ranging from 9000 to 13000 ft. amsl. Due to high altitude and low humidity, the radiation level is amongst the highest in the world (up to 6-7 Kwh/mm), which increases aridity of soils in this region. Longer photoperiod (>12 hours) and about 330 sunny days in a year, that causes extra dryness to the soils are typical characteristics of the soils in this region. These conditions make the agriculture and allied practices very tough nevertheless, by diverting glacial fed rivers into stone built terraces, gathering soil through sedimentation, enriching the soil with organic manure and other practices by which local farmers are able to cultivate staples under such harsh climatic conditions in this region. Cultivation and habitations in the Ladakh region are mostly confined to the river valleys, like Indus valley, Nubra-Shyok valley, Shingo-Suru valley and Zanskar valley.

### 4.2.2 Soil sampling, processing and digestion

For the study, pasture land soil, road side soil and river (Indus or Sindhu) sediments are selected for preliminary data generation for this region in regarding to essentiality for plant and animals. However, 66 composite soil samples from pasture land (06 from each sampling site, total site: 11), 96 samples from road side soils (06 from each sampling site, total site: 16) and 66 Indus river sediment samples (06 from each sampling site, total site: 11). Ten sampling points were selected at each sampling site (100 × 20 m size); thereafter one soil sample was collected from up to 15 cm soil depth (plough layer) by quartering method from each sampling point. All soil samples were air dried at room temperature, sieved with <2.0mm test sieve and further it was grinded in stainless steel pestle and mortar and sieved with 200µm of test sieve. All the soil samples were digested on dry matter basis, soil samples were digested by using metal grade HF (hydrofluoric acid), nitric acid and hydrochloric acid, samples were digested on 42 blocks Automated Hot Bock digestion system (Questron Technologies Inc, Canada). Essential mineral elements were estimated by ICP-OES (Optima 7000 DV, Perkin Elmer, USA).

### 4.2.3 ICP-OES optimized instrumental conditions

| | |
|---|---|
| Injector | : Alumina 2 mm i.d. |
| Sample tubing | : Standard 0.76 mm i.d. |

| | |
|---|---|
| Drain tubing | : Standard 1.14 mm i.d. |
| Quartz torch | : Single slot |
| Sample capillary | : Teflon 1 mm i.d. |
| Sample vials | : Polypropylene |
| Source equilibrium delay | : 15 sec |
| Plasma aerosol type | : Wet |
| Nebulizer start up | : Instant |
| RF power | : 1450 |
| Nebulizer flow | : 0.8 L/min |
| Auxiliary flow | : 0.2 L/min |
| Plasma flow | : 15 L/min |
| Sample pump rate | : 1.5 ml/min |
| Plasma viewing | : Axial, radial |
| Processing mode | : Peak area |
| Auto integration (min-max) | : 0.1-0.5 sec |
| Replicates | : 2 |
| Background correction | : 2-point |

#### 4.2.4 Statistical analysis

Data generated through the study were analyzed for mean and Standard error (SE). Significance level ($P<0.05$) was generated among the different soils (Indus river sediment, Pasture land and road side soils), by one way ANOVA for Duncan Multiple Range Test (DMRT) using the SPSS statistical software, 11.5 version, SPSS Inc. USA (SPSS, 1999).

### 4.3 Result

The iron and magnesium concentrations in various soil systems from the cold desert high altitude region were presented in (Table 4.1, 4.2, 4.3). Our experimental results revealed that, Fe content varied from 9520 to 65660 mg/kg, whereas total mean concentration 32027.22±2026.57 mg/kg. Statistical analysis (one way ANOVA) disclosed that, sampling site 5 (58110 ±3146.80 mg/kg) was reported significantly ($P<0.05$) higher for Fe content while significantly ($P<0.05$) lower concentration at site 8 (11602 ±858.17 mg/kg) in pasture land (Table 4.1). The manganese and zinc concentrations in various soils at cold desert high altitude region were presented in

Table 4.1, 4.2, 4.3. The total average content of Mn in pasture land, Indus river sediment and road side soils were found to 583.33±34.21, 661.28±118.77 and 582.99±20.71 mg/kg respectively, while they varied from 197.70-1089.00, 166-6603.00 and 300.30-1209.00 mg/kg respectively (Table 4.1, 4.2, 4.3). The statistical analysis revealed that, Mn concentration was significantly ($P<0.05$) higher estimated at site 4 (927.68±59.87 mg/kg) and lower at site 8 (225.48±11.14 mg/kg) while at site 2 (1855.52±1202.94 mg/kg) and at site 4 (260.10 ±35.24 mg/kg), whereas at site 2 (940.46±47.39 mg/kg) and at site 14 (346.33±27.78 mg/kg) in pasture land, Indus river sediment and road side soils respectively (Table 4.1, 4.2, 4.3).

The total mean concentration of Zn was reported to 84.87±7.91, 191.86±143.95 and 79.14±4.39 mg/kg respectively in pasture land, Indus river sediment and road side soils, while it ranged varied from 3.75-242.90, 17.48-7804.00 and 2.95-220.70 mg/kg respectively in pasture land, Indus river sediments and road side soils (Table 4.1, 4.2, 4.3). The one way ANOVA (Duncan's multiple range test) analysis revealed that, significantly ($P<0.05$) higher content of Zn was estimated at sampling site 5 (181.66±20.15 mg/kg) and lower at site 8 (11.76±2.53 mg/kg) in pasture land (Table 4.1), while in Indus river sediment, Zn concentration significantly ($P<0.05$) higher was examined at site 2 (1628.7±1543.90 mg/kg) and lower at site 8 (21.59±3.02 mg/kg) (Table 4.3). Road side soils observed significantly ($P<0.05$) higher Zn concentration at site 2 (132.63±11.56 mg/kg) and lower at site 14 (42.05±6.77 mg/kg) (Table 4.2). B concentration ranged from 1.71-212.60, 2.24-5653.00 and 6.44-141.30 mg/kg and the total mean concentration was observed to 80.10±7.06, 151.62±103.89, 36.41±2.53 mg/kg respectively in pasture land, Indus river sediment and road side soils (Table 4.1, 4.2, 4.3). Boron concentration was estimated significantly ($P<0.05$) lower at site 9 (15.22±2.84 mg/kg) and higher at site 5 (163.88±26.36 mg/kg) in pasture land (Table 3.1) while it was significantly ($P<0.005$) higher reported at site 2 (1201.57 ±1112.90 mg/kg) and lowest at site 8 (1201.57±1112.90 mg/kg) in river sediment (Table 4.3) but in road side soils, B concentration was reported higher at site 15 (89.90±12.96 mg/kg) and lower at site 13 (10.44±1.65 mg/kg) (Table 4.2).

**Table 4.1:** Certain essential minerals contents (mg/kg) in pasture land soils from cold desert high altitude region

| Study sites | Fe | Mg | Mn | Zn | Cu | Co | B |
|---|---|---|---|---|---|---|---|
| 1 | 36258$^{e}$ ±2715 | 6399$^{b}$ ±626 | 795.34$^{c}$ ±81.63 | 80.70$^{c}$ ±4.95 | 25.63$^{cd}$ ±3.3 | 19.07$^{bcd}$ ±1.8 | 118.68$^{d}$ ±9.3 |
| 2 | 36420$^{e}$ ±4713 | 5605$^{b}$ ±545 | 804.78$^{c}$ ±102.63 | 112.28$^{d}$ ±13.19 | 31.85$^{de}$ ±7.2 | 20.20$^{bcd}$ ±3.2 | 99.73$^{cd}$ ±13.5 |
| 3 | 44076$^{f}$ ±1620 | 9629$^{c}$ ±376 | 835.54$^{c}$ ±15.29 | 130.86$^{d}$ ±16.42 | 30.81$^{d}$ ±1.4 | 23.73$^{cde}$ ±0.6 | 108.74$^{cd}$ ±6.8 |
| 4 | 50500$^{f}$ ±3750 | 10906$^{c}$ ±1639 | 927.68$^{c}$ ±59.87 | 172.50$^{e}$ ±17.27 | 37.7d$^{ef}$ ±2.9 | 28.86$^{de}$ ±2.1 | 126.70$^{d}$ ±2.9 |
| 5 | 58110$^{g}$ ±3147 | 15414$^{d}$ ±2031 | 780.14$^{c}$ ±50.27 | 181.66$^{e}$ ±20.15 | 45.98$^{f}$ ±3.4 | 31.11$^{e}$ ±2.0 | 163.88$^{e}$ ±26.4 |
| 6 | 26220$^{cd}$ ±1831 | 1803$^{a}$ ±130 | 477.68$^{b}$ ±29.14 | 72.17$^{bc}$ ±6.72 | 18.21$^{bc}$ ±1.3 | 14.90$^{abc}$ ±0.6 | 44.40$^{ab}$ ±4.1 |
| 7 | 20618$^{bc}$ ±1215 | 3770$^{ab}$ ±392 | 418.20$^{b}$ ±26.40 | 44.26$^{ab}$ ±7.25 | 12.57$^{ab}$ ±1.7 | 11.71$^{ab}$ ±1.1 | 22.44$^{a}$ ±4.5 |
| 8 | 11602$^{a}$ ±858 | 4468$^{ab}$ ±635 | 225.48$^{a}$ ±11.14 | 11.76$^{a}$ ±2.53 | 4.81$^{a}$ ±0.7 | 6.52$^{a}$ ±0.6 | 40.26$^{ab}$ ±22.1 |
| 9 | 13948$^{ab}$ ±1705 | 4961$^{b}$ ±1450 | 384.88$^{b}$ ±38.29 | 22.37$^{a}$ ±6.64 | 4.21$^{a}$ ±0.7 | 7.61$^{a}$ ±1.3 | 15.22$^{a}$ ±2.8 |
| 10 | 25674$^{cd}$ ±1527 | 4205$^{ab}$ ±579 | 354.78$^{ab}$ ±12.24 | 66.72$^{bc}$ ±8.52 | 43.20$^{e}$f ±8.3 | 46.93$^{f}$ ±8.9 | 75.96$^{bc}$ ±9.8 |
| 11 | 32568$^{de}$ ±2298 | 3328$^{ab}$ ±467 | 480.96$^{b}$ ±46.13 | 55.77$^{bc}$ ±3.57 | 61.50$^{g}$ ±2.2 | 48.26$^{f}$ ±1.4 | 74.45$^{bc}$ ±4.8 |
| Mean | 32027 ±2026 | 6325 ±585 | 583.33 ±34.21 | 84.87 ±7.91 | 28.60 ±2.6 | 23.4 ±2.1 | 80.00 ±7.10 |
| Range | 9520-65660 | 1346-19780 | 197.70-1089.00 | 3.75-242.90 | 2.27-67.9 | 4.51-56.8 | 1.71-212.6 |

Value (Mean±SE, N=6) bearing different superscripts differ significantly (P<0.05) between the row.

**Table 4.2:** Certain essential minerals concentration (mg/kg) in road side soils from cold desert high altitude region

| Study sites | Fe | Mg | Mn | Zn | Cu | Co | B |
|---|---|---|---|---|---|---|---|
| 1 | $30182^{bc}$ ±3185 | $4769^{bcd}$ ±1093 | $441.92^{abc}$ ±29.62 | $60.83^{a}$ ±4.16 | $54.4^{e}$ ±3.5 | $52.6^{e}$ ±2.8 | $52.30^{d}$ ±8.6 |
| 2 | $49270^{f}$ ±677 | $10289^{e}$ ±1491 | $940.46^{g}$ ±47.39 | $132.63^{cd}$ ±12.00 | $32.8^{c}$ ±4.8 | $24.8^{d}$ ±2.3 | $73.80^{e}$ ±13.70 |
| 3 | $28414^{b}$ ±1869 | $1980^{a}$ ±354 | $479.58^{abcd}$ ±31.42 | $59.74^{a}$ ±13.61 | $14.3^{ab}$ ±2.7 | $12.8^{b}$ ±1.4 | $23.10^{abc}$ ±2.10 |
| 4 | $31958^{bc}$ ±1917 | $1493^{a}$ ±160 | $540.60^{bcde}$ ±40.02 | $46.64^{a}$ ±4.30 | $45.6^{d}$ ±1.0 | $57.7^{e}$ ±0.7 | $32.10^{bc}$ ±0.80 |
| 5 | $33960^{bcd}$ ±2843 | $1444^{a}$ ±81 | $528.28^{bcde}$ ±46.55 | $57.89^{a}$ ±3.39 | $44.4^{d}$ ±1.1 | $58.2^{e}$ ±0.5 | $29.7^{abc}$ ±1.30 |
| 6 | $30765^{bc}$ ±1007 | $1559^{a}$ ±114 | $420.70^{ab}$ ±14.81 | $40.67^{a}$ ±7.94 | $49.9^{de}$ ±0.7 | $57.7^{e}$ ±0.3 | $32.5^{bcd}$ ±1.20 |
| 7 | $33962^{bcd}$ ±4031 | $2177^{ab}$ ±389 | $513.43^{bcde}$ ±67.00 | $56.69^{a}$ ±6.79 | $46.4^{de}$ ±1.4 | $56.6^{e}$ ±1.8 | $31.7^{bc}$ ±2.50 |
| 8 | $28605^{b}$ ±808 | $1217^{a}$ ±99 | $404.53^{ab}$ ±14.80 | $59.93^{a}$ ±5.84 | $45.9^{de}$ ±0.7 | $58.3^{e}$ ±0.5 | $34.2^{bcd}$ ±1.50 |
| 9 | $34288^{bcd}$ ±3428 | $1493^{a}$ ±174 | $485.92^{abcde}$ ±34.20 | $56.78^{a}$ ±5.29 | $48.7^{de}$ ±2.9 | $55.9^{e}$ ±1.2 | $35.3^{bcd}$ ±3.50 |
| 10 | $42522^{def}$ ±2278 | $4013^{abc}$ ±239 | $784.50^{f}$ ±29.54 | $112.66^{cd}$ ±8.50 | $18.5^{b}$ ±0.6 | $15.7^{bc}$ ±1.3 | $26.9^{abc}$ ±1.50 |
| 11 | $37162^{bcd}$ ±2319 | $3415^{ab}$ ±246 | $635.92^{e}$ ±49.11 | $114.57^{cd}$ ±9.60 | $14.8^{ab}$ ±1.0 | $12.4^{b}$ ±1.1 | $21.8^{abc}$ ±1.60 |
| 12 | $49144^{f}$ ±4704 | $6469^{cd}$ ±1585 | $786.06^{f}$ ±66.76 | $127.50^{cd}$ ±24.00 | $20.9^{b}$ ±4.8 | $20.2^{cd}$ ±3.1 | $37.8^{cd}$ ±12.30 |
| 13 | $39772^{cde}$ ±3849 | $1443^{a}$ ±178 | $579.36^{cde}$ ±35.86 | $71.87^{ab}$ ±11.5 | $15.0^{ab}$ ±1.0 | $14.8^{bc}$ ±0.6 | $10.4^{a}$ ±1.60 |
| 14 | $19273^{a}$ ±2326 | $1605^{a}$ ±361 | $346.33^{a}$ ±27.78 | $42.05^{a}$ ±6.77 | $7.7^{a}$ ±0.9 | $7.0^{a}$ ±0.8 | $15.6^{ab}$ ±2.40 |
| 15 | $47888^{ef}$ ±4592 | $7094^{d}$ ±2432 | $848.12^{fg}$ ±93.58 | $139.06^{d}$ ±18.5 | $32.4^{c}$ ±5.7 | $23.9^{d}$ ±3.4 | $89.9^{e}$ ±12.90 |
| 16 | $39136^{cde}$ ±2967 | $2234^{ab}$ ±249 | $627.10^{de}$ ±43.44 | $102.38^{bc}$ ±14.00 | $19.4^{b}$ ±2.3 | $16.5^{bc}$ ±1.8 | $28.3^{abc}$ ±4.80 |
| Mean | 36099 ±1062 | 3249 ±337 | 582.99 ±20.71 | 79.14 ±4.39 | 33.7 ±1.7 | 36.4 ±2.3 | 36.40 ±2.50 |
| Range | 15490-63570 | 802-15900 | 300.30-1209 | 2.95-220.7 | 5.9-68.7 | 5.9-62.9 | 6.40-141.3 |

Value (Mean±SE, N=6) bearing different superscripts differ significantly ($P<0.05$) between the row.

Table 4.3: Certain essential minerals content (mg/kg) in river (Indus) sediment from cold desert high altitude

| Study sites | Fe | Mg | Mn | Zn | Cu | Co | B |
|---|---|---|---|---|---|---|---|
| 1 | 44760[ef] ±6192 | 5214[cd] ±682 | 685.88[ab] ±57.83 | 72.33[a] ±7.74 | 21.32[a] ±2.5 | 18.10[ab] ±1.1 | 36.43[a] ±1.6 |
| 2 | 21450[ab] ±8294 | 5096[bcd] ±771 | 1855.52[c] ±1203 | 1628.79[b] ±1544 | 1016[a] ±1002 | 1291[c] ±1279 | 1202[b] ±1112 |
| 3 | 48750[f] ±1239 | 5157[bcd] ±87 | 949.58[ab] ±16.44 | 119.88[a] ±6.84 | 40.57[a] ±2.2 | 25.74[a] ±0.6 | 51.95[a] ±8.7 |
| 4 | 32044[bcd] ±640 | 2620[bc] ±308 | 446.18[a] ±10.50 | 56.11[a] ±3.38 | 60.93[a] ±1.3 | 51.91[ab] ±0.5 | 66.08[a] ±6.3 |
| 5 | 13643[a] ±1392 | 2161[a] ±223 | 260.10[a] ±35.24 | 98.95[a] ±2.44 | 38.57[a] ±1.6 | 63.45[ab] ±0.7 | 29.96[a] ±3.3 |
| 6 | 35180[cde] ±2780 | 4195[abcd] ±219 | 556.23[a] ±28.72 | 71.03[a] ±6.86 | 19.40[a] ±1.3 | 16.07[ab] ±0.5 | 51.74[a] ±2.4 |
| 7 | 38510[cdef] ±1924 | 7744[e] ±2116 | 668.36[ab] ±74.01 | 85.67[a] ±22.91 | 21.29[a] ±3.0 | 16.65[ab] ±1.8 | 56.92[a] ±15.7 |
| 8 | 42769[def] ±2107 | 6336[de] ±784 | 490.93[a] ±25.97 | 127.47[a] ±3.97 | 35.39[a] ±1.1 | 24.78[ab] ±0.6 | 94.33[a] ±2.7 |
| 9 | 22044[ab] ±842 | 3659[abc] ±389 | 377.26[a] ±21.23 | 38.56[a] ±6.68 | 9.60[a] ±0.7 | 10.21[ab] ±0.4 | 6.99[a] ±1.7 |
| 10 | 30552[bc] ±1864 | 2364[a] ±222 | 546.50[a] ±27.62 | 66.18[a] ±7.32 | 18.44[a] ±1.4 | 15.78[ab] ±1.1 | 40.70[a] ±13.8 |
| 11 | 20795[ab] ±4192 | 3939[abcd] ±179 | 288.43[a] ±13.92 | 21.59[a] ±3.02 | 6.22[a] ±0.4 | 8.09[a] ±0.5 | 1.03[a] ±1.4 |
| Mean | 32068 ±1787 | 4416 ±313 | 661.28 ±118.77 | 191.86 ±143.95 | 119 ±92.6 | 121 ±118 | 151.6 ±104 |
| Range | 186.50 -68040 | 1549 -16160 | 166 -6603 | 17.48 -7804 | 5.29 -5025 | 7.08 -6407 | 2.3 -5653 |

Value (Mean±SE, N=6) bearing different superscripts differ significantly ($P<0.05$) between the row.

## 4.4 Discussion

### 4.4.1 Iron (Fe)

Iron is a structural component of porphyrin molecules: cytochromes, hemes, hematin, ferrichrome and leghemolobin, all these substances are involved in oxidation-reduction reactions in respiration and photosynthesis. Up to 75% of the cell Fe is associated with the chloroplasts and upto 90% of Fe in leaves occur with lipoprotein of the chloroplast and mitochondrial membranes [Havlin et al., 2010]. A high proportion of iron is localized within the chloroplasts of rapidly growing leaves [Marschner, 1995]. Iron occurs in concentrations of 7,000 to 500,000 ppm in soils [Fageria et al., 2002], where it is present mainly in the insoluble Fe (III) (ferric,

$Fe^{3+}$) form. Ferric ions hydrolyze readily to give Fe $(OH)\ 2^{+}$, Fe $(OH)_3$ and Fe $(OH)^{4-}$, with the combination of these three forms and the $Fe3^{+}$ ions being the total soluble inorganic iron [Romheld & Marschner, 1986]. The present study revealed that, the Fe concentration in various study soil systems detected above the critical level and found in optimum quantity for the crop plants growing in the region and the livestock reared over here but just opposite results were predicted by Parmar et al. [1999] in your study in NTPA extractable soil samples, most of the samples were found deficient in Fe from Leh region. Study of Parmar et al. [1999] also revealed the deficient level of Fe, this was the available form of Fe in soil and it may be due to the alkaline pH (7.5-8.8) reaction and calcareous nature of soil. The higher level of Fe was estimated in our present study; comparatively higher level of Fe may be due to the Fe forming minerals in parent materials or in rocks or geological system from this region. The level of Fe in road side soils was found comparatively higher than other studied soils (Indus river sediments and pasture land soil) this is because of road contamination.

**4.4.2 Magnesium (Mg)**

Soil Mg originates from weathering of several Mg bearing minerals including biotite dolomite, illite hornblende olivine and serpentine in arid region substantial amounts of mineral epsomite may be present and in calcareous soils Mg may be found as dolomite [Havlin et al., 2010]. Common soil types high in Mg include soils that are not leached heavily or soils in depressions where leached nutrients may accumulate. Leached soils such as laterite soils and podzols tend to be low on Mg [Kirkby & Mengel, 1976], Soils derived from parent bedrock of dolomite or igneous rock tends to be high in Mg [Kirkby & Mengel, 1976; Fernadez & Merino, 1999]. The Mg deficiency is associated with environmental conditions that occurred in excessively leached sandy soils [Garner et al., 1923]. In my previous study it was predicted that the nature of soils from this region is sandy, alkaline and calcareous it proved the crop production are very problematic and require special attention for soil mineral nutrient management for crop production, all these factors affecting the minerals availability in soil solution. Approximately 13000, 47000, 43000 ppm of the earth crust’s continental upper layer, lower layer and the ocean crust is made up of Mg respectively [Selley et al., 2005]. However in surface soils, Mg concentrations usually ranges from 300 to 8400 ppm, with sandy soils typically having the lowest concentration (500 ppm) and the clay soils containing the highest Mg concentrations (5000 ppm) [Kirkby & Mengel, 1976]. Considering surface soils, sandy soils typically have the lowest Mg concentrations and clay soils typically have the highest Mg concentrations [Mengel & Kirkby, 1982; Bear, 1949]. Mg in soil solutions ranges from 50-120 ppm [Prasad, 2007]. Mg constitutes 19300 ppm of earth crust however total soil Mg content ranges from 1000 ppm in coarse humid region soils to 40000 ppm in fine textured, arid soils formed from high Mg minerals [Havlin et al., 2010]. A soil solution Mg concentration typically ranges from 5-50 ppm in temperate region soils although Mg concentrations between 120 and 2400 ppm have been observed [Havlin et al., 2010]. It is assumed that the total Mg availability in various soils from this region is not a problem here because our present study revealed that the pasture land soil contain 6325 ppm, 4416 river sediment, 3249 ppm in road side soils Mn that is total but may be problem with the availability as the prevailing conditions are not suitable and may affect their availability.

**4.4.3 Manganese (Mn)**

Mn is the tenth most abundant element on the surface of the earth this does not occur in isolation naturally but found in combination with other elements to give many common minerals in soils. Mn deficient soils are found all over the world; in Indian subcontinent [Katyal and Vlek, 1985]; Great Lake regions of Canada and USA and in Atlantic Coastal plains states of USA [Reuter et al., 1988]; in Europe [Welch et al., 1991]; in northern china [Zheng et al., 1982]; in Western Australia and Victoria [Donald & Prescott, 1975]. All these previous studies indicated that Mn deficiency dominated world over and these deficiency lies with the soil quality that is seems to be very poor, results of our study revealed that the Mn concentration in this cold arid region soil systems did not reported deficient as the total Mn is concerned and it differed with soil types.

The average concentrations of Mn in earth crust is 1000 ppm, according to Swine [1955]; vary from 200-3000 ppm, while the typical range in soils is about <1.0-18300 ppm [Wild, 1988]. According to Havlin et al. [2010], total Mn content in soils ranges from between 20-3000 ppm and averages about 600 ppm. The above mentioned reports said, the naturally, soil contains much higher total Mn content than their requirement to plant and animals but the problem is with their availability in soil solution, that is affected by soil pH; it decreases as the pH increases and Mn found in most Fe-Mg rocks when released from the weathering of primary rocks. The Mn deficiency is generally observed on high pH soils, which favour both chemical and microbiological oxidation and immobilization of soluble $Mn^{2+}$. The level of Mn in cold desert high altitude region soils is quite surprising because it found above the 600 ppm in various studied soils that is said to be optimum and above the critical level. The higher level of Mn in cold arid soils may be due to the higher level of Fe in our studied soils soil as it was reported that the Mn is associated with the Fe forming minerals in earth crust, similar prediction reported by Gilkes & McKenzie [1988] according to them Mn is most abundant in soils developed from rocks rich in iron owing to its association with this element.

**4.4.4 Zinc (Zn)**

The average concentration of zinc in the crust of Earth, granitic and basaltic igneous rock is approximately 70, 40 and 100 ppm respectively [Taylor, 1964], whereas sedimentary rocks like limestone, sandstone and shale contain 20, 16 and 95 ppm, respectively [Turekian & Wedepohl, 1961]. The most quoted range of total Zn in normal soils is 10-300 ppm with a mean value of 50 ppm [Vinogradov, 1959]. There are five major pools of zinc in the soil: (a) zinc in soil solution; (b) surface adsorbed and exchangeable zinc; (c) zinc associated with organic matter; (d) zinc associated with oxides and carbonates; and (e) zinc in primary minerals and secondary alumino-silicate materials [Shuman, 1991]. The total zinc content in soils varies from 3 to 770 ppm with the world average being 64 ppm [Kabata-Pendias and Pendias, 1992] and the critical level is <2.5 ppm soils. Our present investigation showed that the Zn level in studied soil ecosystems ranged from 2.95 to 7804.00 mg/kg and total mean content (84.87±7.91 pasture land soil; 191.86±143.95 Indus river sediment and 79.14±4.39 mg/kg road side soils) observed which is much more than the world average and said to be non deficient in total Zinc in cold arid soils. Zinc deficiency is common in plants growing in highly weathered acid or calcareous soils [Trehan & Sekhon, 1977]; the same results also reported by Parmar et al. [1999] in this region which disclosed that the 72 % soil samples collected from different blocks of Leh district were found deficient in DTPA-extractable Zn and 38% in Lahaul Spiti soil samples. Available form of Zn is quite differ with the total Zn in the soil, total consists both available and non available form, availability is affected by soil chemistry (pH, soil reaction) and soil texture (silt, clay & sand proportions) as it was reported by Swaine [1955] and White [1993] that total Zinc content in soil depends upon the parent rock weathering, organic matter, texture and pH.

The total Zn in some Indian soils was 47 ppm in Entisols, 60 ppm in Inceptisols 61 ppm in Aridisols, 63 ppm in Vertisols, 44 ppm in Alfisols 53 ppm in Ultisols, 30 ppm in Molisols and 72 ppm in Oxisols [Katyal & Sharma, 1991]. The soils of Leh-Ladakh (cold arid high altitude) characterize as typic Cryorthids (cold deserts), have 84.87, 191.86, 86.66 and 79.14 ppm Zn concentrations from our present study in pasture land, Indus river sediment, agriculture soil and road side soils respectively. It was reported that the soils formed from basic rocks such as basalt are richer in Zn than those from acid rocks such as granite gneisses [Vinogradov, 1959] total Zn content in soils is generally lower in lighter soils and higher in heavier soils for example in Ontario (Canada) sandy soils had 46 ppm while clayey soils had 62 ppm Zn [Frank et al., 1976]. The low availability of Zn in alkaline calcareous soils is one of the widest ranging chlorotic stresses in the world agriculture especially in cereals in Australia, Turkey, India, Pakistan and China [Marschner, 1995; Cakmak, 2004; Singh et al., 2005]. A global study was initiated by FAO recorded Zn deficiency in 50% soil samples were collected from 25 countries [Sillanpaa, 1982], in India Zn also has received special attention of researchers [Katyal et al., 2004; Prasad, 2006] and earlier investigations revealed that the most of the Indian soils are found Zn deficient.

**4.4.5 Copper (Cu)**

The total mean concentrations of Cu (uncontaminated) in worldwide soils range from 13-24 ppm, but the overall range for world soils is higher (1-40 ppm), depending on the nature of the soil parent materials [Kabata-Pendias & Pendias, 1992]. Soils with an elevated copper concentration (<70 ppm), can be used for growing all crops. The present study revealed that, total average copper concentrations varied from to 28.60±2.6 to 119±92.6 ppm in our studied soils and sediments, that is much more than the world average content in soils [Kabata-Pendias & Pendias, 1992] however it is considered risky somewhere in study sites values are >100 ppm, that is in the Indus ricer sediments [Eduardo et al., 2010 & Alvarenga, 2006]. Thus precaution should be taken when using the Indus river sediment and somehow to water but the other studied soils are in the safe zone as per the Cu concentration is concerned. The elevated level of copper is found in mafic rocks (60-120 ppm) and argillaceous sediments (40-60 ppm) much lower levels in limestones (2-10 ppm) [Kabata-Pendias & Pendias, 1992]. However, Cu >100 ppm in the soils is lethal for most common plants [Eduardo et al., 2010 & Alvarenga, 2006]. Copper concentration is soils is strongly differentiated and indicates a relevant relation with clay content in soils [Terelakh et al., 2000; Kabata-Pendias & Pendias, 1999].

Cu in soil can be fixed by adsorption, precipitation, organic Chelation and complexation as well as microbial fixation, basically immobile in soils [Kabata-Pendias & Pendias, 1992], Cu can precipitate with sulfides, carbonates and hydroxides and is tightly held on organic and inorganic exchange sites, with the bilk of Cu adsorption occurring in Fe and Mn oxides [Kabata-Pendias & Pendias, 1992], which is non exchangeable form [Tisdale et al., 1985]. The major form of Cu in soil solution is that of soluble organic chelates, while the solubility of all Cu forms decreases at pH 7.0-8.0 [Kabata-Pendias & Pendias, 1992]. Acid leached sandy soils and calcareous sandy soils may be low in soluble copper [Tisdale et al. 1985] and mobility is low in reduced and neutral sols [McBride, 1994]. Cu mobility may be higher under high pH due to the $Cu^{2+}$ complexes formation which may increase overall Cu solubility [McBride, 1994] this factor can play a major role in total Cu dynamics at this present study region.

**4.4.6 Cobalt (Co)**

The overall range of cobalt in soils on a worldwide basis is 0.1 to 70 ppm [Kabata-Pendias & Pendias, 1992] and the total mean content is 8 ppm [Tisdale et al., 1985] further typical range is world soils is 0.3-200 ppm [Wild, 1988] . Cobalt is present is soil as $Co^{2+}$ and $Co^{3+}$ and probably as $Co(OH)^{3-}$ [Kabata-Pendias & Pendias, 1992] and major form of cobalt in soil solution is $Co^{2+}$ [McBride, 1994] while the total amount of Co in soil solution will be low. The status of available Co in soil can be estimated based on geological and soil information [Kabata-Pendias & Pendias, 1992]. The manganese oxide minerals are most imperative factor controlling Co distribution and their availability in the soils [Kabata-Pendias & Pendias, 1992; McKenzie, 1975], so the crystalline Mn oxide minerals may retain almost all soil Co, even that the applied to soil as fertilizer [Tisdale et al., 1985], Co held in such a way in soils is not available for the plants. Further Fe oxide, clay minerals and organic matter may also adsorb Co so the availability is again influenced by the clay mineral types and organic matter on which it is absorbed [Kabata-Pendias & Pendias, 1992]. Montmorillonite and illite will strongly retain Co and organic chelates bound Co which is very mobile in soils, Co is mobile in oxidizing and acid soils; soils with low Co levels tend to be either alkaline and calcareous, high in organic matter content, acidic and highly leached and high in Fe and Mn contents in soils [Kabata-Pendias & Pendias, 1992]. Our findings disclosed that Co concentration in various soils and river sediment was within the typical range of world soils [Wild, 1988; Kabata-Pendias & Pendias, 1992] and below the average level in soils [Tisdale et al., 1985]. Further these present results regarding the Co concentrations were found below threshold limit [Eduardo et al. 2010 & Alvarenga, 2006] in our studied soils and sediments samples. The low abundance of Co in the soils of the study area possibly does not impart threat of Co in human beings through food chain because it is essential trace elements for plants, animals and mankind as well. Alkaline and calcareous soil, organic matter and high Fe reduce the mobility of Co. Biological function of Co is not very clearly understood but it is considered essential for the plants in minor quantities. The soil contaminations of heavy metals were studied in different parts of India [Parkpian et al., 2003; Singh et al., 2003].

**4.4.7 Boron (B)**

B occurs in low concentrations in the earth's crust and in most igneous rocks (<10 ppm), among the sedimentary rocks, shale have the highest B content (<100 ppm) present in the clay minerals. The total B concentration in soils varied between 2 and 200 ppm and frequently ranges from 7-80 ppm [Havlin et al., 2010]. The total boron content of most agricultural soils ranges from 1-467 ppm with an average content of 9-85 ppm and the available B in agriculture soils varies from 0.5-5.0 ppm. Gupta [1968] reported that the total boron on Podzols soils from eastern Canada ranged from 45-124 ppm. Total B in major soil orders, Inceptisols and Alfisols. Our present study disclosed total B concentrations in various soils to be 36.4, 80.0 and 151.6 mg/kg respectively in road side soil, pasture land soil and Indus river sediment while the B contents in Indian soils ranged from 8-18 mg/kg [Borkakati & Takkar 1996]. These reports showed that the B concentrations in cold arid soils are comparatively higher than the national range, these higher concentrations may be due to the B forming minerals in parent rocks and soil types falling under divergent geographical and climatic zones. The available form of B in soil is believed to be derived from sediment and plant materials, B leaches down the soil profile and therefore soils of humid region such as sandy podzols, alluvial soils and organic soils have low amounts of plant available B, because B minerals are too much soluble [Lindsay, 1991]. Gupta [1968] reported that available boron on Podzol soils from eastern Canada ranged from 0.38-4.67 ppm. It indicates the very less amount of B is available in soil for the plant in soil solution. B availability is affected by Soil reaction or soil pH as earlier workers observed negative correlations between plant B accumulations and soil pH [Gupta, 1972]. Therefore the availability of B may be also influenced in this studies region where soil reaction is alkaline or higher range of pH and other factors may also be involved viz. coarse soil texture, low water holding capacity, leachability, topography and moisture.

## 4.5 Conclusion

Results of the present investigation showed that the essential minerals nutrients (total Fe, Mg, Mn, Zn, Cu, Co and B) are widely distributed and are within the normal range of soils at various studied sites at cold desert high altitude microclimate. Hence, it could be speculated that fodder/plants grown on these sites will be suitable for livestock feeding. However, various fodder/plants grow on these sites should be analyzed for minerals content and minerals supplementation, if required.

# CHAPTER V

## To evaluate certain essential minerals availability in irrigation, stagnant and river (Indus) water of cold desert high altitude region

**Abstract**

The availability and accumulation of essential mineral nutrients in water has enormous impact on the living beings of prevailing ecosystem because mineral elements concentration changed according change in climatic factors of the ecosystems. Plant, animal, human being and ecosystem are severely affected by proportion of the mineral elements, because above systems needed all these mineral elements in different amount. Therefore the present study was conducted with the aim to screen out availability and accumulation of essential mineral elements in regarding to their health response. The study was done in cold desert high altitude microclimate (Leh-Ladakh) which lies in Tibetan Plateau. Samples were collected from the available water resources viz. irrigation water, Indus River and stagnant water (ponds) and analyzed for magnesium Mg, Mn, Fe, Zn and B. The total mean concentration of Fe, Mg, Mn, Zn and B in irrigation water were reported to 0.360±0.04, 6.966±0.29, 0.058±0.006, 0.220±0.034 and 1.332±0.09 ppm, respectively, whereas their range differed from 0.053-1.712, 1.135-13.120, 0.025-0.219, 0.060-0.1724 and 0.011-2.730 ppm, respectively. Total average values of Fe, Mg, Mn, Zn and B were examined to be 0.403±0.05, 7.832±0.39, 0.055±0.005, 0.332±0.083 and1.346±0.10 ppm respectively; their range differed from 0.020-1.884, 2.323-16.320, 0.027-0.209, 0.018-5.188 and 0.122-4.745 ppm respectively in stagnant water. The Fe, Mg, Mn, Zn and B in Indus river water were differed widely and observed to be ranged from 0.087-3.005, 3.593-11.00, 0.030-0.129, 0.065-6.718 and 0.323-2.457 ppm respectively, whereas, total average concentrations were reported to 0.581±0.11, 8.181±0.25, 0.047±0.004, 0.341±0.188 and 1.467±0.11 ppm respectively. The results revealed that the most of mineral elements are below the optimum level, under the maximum permissible limit and water sources from this region are considered good for health of living beings and the environment of this cold arid region.

**Key words:** Essential minerals, cold desert, high altitude, Indus river water, minerals availability

## 5.1 Introduction

Water is an essential nutrient which is involved in all basic physiological functions of the body. However, it is important to note that water relative to other nutrients, is consumed in considerably larger quantities. Therefore, water availability and quality are extremely important for animal health and productivity. Limiting water availability to livestock will depress production rapidly and severely and poor quality drinking water is often a factor limiting intake. Considering that water is consumed in large quantities, if water is poor quality, there is an increased risk that water contaminants could reach a level that may be harmful. Most of the major and trace mineral elements in drinking water are naturally occurring and they come by contact of water with rocks, soil and effects of the geological setting, including climate [NAS, 1977; WHO, 1998], however, the chemical composition of drinking water also depends on the contaminating effects of industry, human settlements, agricultural activities and water treatment and distribution [NAS, 1977; WHO, 1998]. Every form of living matter requires these inorganic elements for their normal life processes [Hays and Swenson, 1985]. The importance of mineral elements in human, animal and plant nutrition has been well recognized [Underwood, 1971] deficiencies or disturbances in nutrition of an animal can cause a variety of diseases and can arise in several ways.

The presence of mineral elements in animal feed is vital for the animal's metabolic processes. Grazing livestock from tropical countries often do not receive mineral supplementation except for common salt and must depend almost exclusively upon forage for their mineral requirements [McDowell et al., 1984]. Mineral deficiencies or imbalances in soils affect the mineral nutrient of feed/forages and water prevail over and cause low animal production and reproductive problems. Plants use these minerals as structural components in carbohydrates and proteins; organic molecules in metabolism, such as magnesium in chlorophyll and phosphorus in ATP; enzyme activators like potassium and for maintaining osmotic balance [Prasad, 2007]. At 1600 ppm, iron caused significant reductions in daily gains and feed intake [Standish et al., 1969]. In calves, poorer performance may occur at dietary iron levels of 500 ppm or more [Koong et al., 1970].

Magnesium (Mg) is involved in the function of enzymes of carbohydrate, lipid, protein and nucleic acid metabolisms [SCF, 1993; Saris, 2000], essential for the mineralization and development of skeleton and also plays a role in cellular permeability and neuromuscular excitability [SCF, 1993; Saris, 2000]. Mg deficiency of this element has been implicated in hypertension and type II diabetes [Saris, 2000]. A common form of Mg deficiency is tetany. In ruminants it is called grass tetany or wheat-pasture poisoning. High level of sodium intake for prolonged period of time may disturb normal homeostasis, potentially can lead to some forms of hypertension, congestive cardiac failure, renal disease, cirrhosis, toxemia of pregnancy. Lactating cows consuming water with a high salt content (sodium salt) increased water intake by 7% and exhibited a tendency for less milk yield compared to cows consuming low saline water

[Jaster et al., 1978]. Iron deficiency, causing varying degrees of impairment in cognitive performance, lowered work capacity, lowered immunity to infections, pregnancy complications e.g. babies with low birth weight, poor learning capacity and reduced psychomotor skills [Batra and Seth, 2002], very severe anaemia is a direct cause of maternal and child mortality [Chakravarty and Ghosh, 2000]. Calcium is highly implicated in the maintenance of firmness of fruits [Olaiya, 2006] and its requirements in fruits are related to cell wall stability and membrane integrity [Belakbir et al., 1998].

Drinking water is probably the most common source of excessive intake of S in livestock. From the perspective of water quality for farm animals, sulphur is probably the most significant water contaminant in ruminant livestock, having considerable impact on both health and performance. Higher levels of sulphur in drinking water can be tolerated by animals such as pigs or poultry, whereas relatively low levels can be detrimental to health and performance in cattle or sheep. In recent years, many reports implicated high levels of S in the drinking water as an etiological factor in S induced brain tissue necrosis commonly known as polioencephalomalacia [Kul et al., 2006; McKenzie et al., 2004].To assess the dietary intake and adequacy of minerals, information needs to be collected on mineral element content of foods, diets and water [Simsek and Aykut, 2007]. By keeping the above problems in mind, the present study was planned with the objectives to investigate the availability and accumulation of major and trace mineral nutrients in regarding to the plant, animal and human health in cold desert high altitude microclimate of India.

## 5.2 Material and Methods

### 5.2.1 Survey of study site

Present study was conducted in Leh district of Ladakh division in India and study sites were presented in table 5.1, 5.2, 5.3. The water resources available over the Leh-Ladakh region mostly made from the glacier water through the snowfall and very less contribution with rainwater only during the summer season. The irrigation water used here comes through the rivers (Indus or Zanskar), somewhere it comes from the glaciers during the summer season and very less use of ground water.

**Table 5.1:** Study sites of irrigation water from cold desert high altitude microclimate

| Study Sites | Name of site | Altitude (ft. amsl) | Distance from Leh city (km) | Distance from highway (km) | Distance from local market (km) | Distance from industry (km) | Distance from air port (km) |
|---|---|---|---|---|---|---|---|
| 1 | Choglamsar | 10573±26.2 | 15 | 0.150 (Leh-Manali) | 0.150 | 0.175 (mini steel firm) | 25 |
| 2 | Ranbirpura | 10766±19.4 | 38 | 0.150 | 0.150 | 0.800 (Concrete manufacturing unit) | 47 |
| 3 | Ranbirpura | 10796±17.9 | 36 | 0.100 | 0.100 | 1.0 (Concrete manufacturing unit) | 46 |
| 4 | Ranbirpura | 10886±29.8 | 35 | 0.050 | 0.050 | Concrete manufacturing unit | 45 |
| 5 | C. Gogma | 10752±16.3 | 40 | 25 | 25 | 27 (small steel firm) | 48 |
| 6 | C. Gogma | 10850±13.5 | 42 | 27 | 27 | 29 (small steel firm) | 50 |
| 7 | C. Gogma | 10725±72.1 | 41 | 26 | 26 | 28 (small steel firm) | 49 |
| 8 | Thiksey | 10705±17.0 | 31 | 1.0 | 1.0 | 5.8 (Concrete manufacturing unit) | 41 |
| 9 | Thiksey | 10766±25.1 | 30 | 0.300 | 0.300 | 6.0 (Concrete manufacturing unit) | 40 |
| 10 | Shey | 10630±34.8 | 30 | 0.500 | 0.400 | 16 (Concrete manufacturing unit) | 38 |
| 11 | Spituk | 10539±11.4 | 10 | 1.0 | 0.300 | 15 (LPG bottling plant) | 0.5 |

Mostly water flowing in the rivers, come from the malting out of the glaciers in this region. Ecologically Ladakh region lays in Tibetan Plateau is a cold arid region under the rain shadow of the Himalayas and study map in given in figure 5.1. Leh district is situated between $32^0$ to $36^0$N latitude and $75^0$ to $80^0$E longitude and at an altitude ranging from 9666 to 19666 ft. amsl. The study area lies between 33°59.362 to 34°17.722 N latitude and 077°12.023 to 077°45.669 E longitude and with at an elevation ranging from 9000 to 14000 ft. amsl. Annual temperature in this region ranges from $-30^0$C to $+40^0$C. Annual minimum and maximum average temperature is $-1.46^0$C and $+13.48^0$C, respectively and annual minimum and maximum average relative humidity is 24.70 and 39.03%.

**Table 5.2:** Study sites of stagnant water (pond) from cold desert high altitude microclimate

| Study Sites | Name of site | Altitude (ft. amsl) | Distance from Leh city (km.) | Distance from highway (km) | Distance from local market (km.) | Distance from industry (km.) | Distance from air port/air force station (km.) |
|---|---|---|---|---|---|---|---|
| 1 | Choglamsar | 10552±34.0 | 14.5 | 0.200 (Leh-Manali) | 0.200 | 0.400 (small steel firm ) | 26 |
| 2 | Choglamsar | 10.592±56.3 | 15 | 0.100 (Leh-Manali) | 0.100 | 0.600 (small steel firm ) | 26 |
| 3 | C. Gogma | 10850±13.5 | 42 | 32 (Leh-Manali) | 32 | 34 (small steel firm ) | 51 |
| 4 | Thiksey | 10766±25.1 | 35 | 0.100 (Leh-Manali) | 0.100 | 6 (Concrete manufacturing unit) | 44 |
| 5 | Thiksey | 10715±19.1 | 36 | 0.300 (Leh-Manali) | 0.300 | 7 (Concrete manufacturing unit) | 45 |
| 6 | Shey | 10630±34.8 | 24.5 | 1.0 (Leh-Manali) | 1.0 | Nil | 34 |
| 7 | Shey | 10696±16.1 | 25 | 0.600 (Leh-Manali) | 0.600 | Nil | 35 |
| 8 | Shey | 10750±19.5 | 26 | 0.100 (Leh-Manali) | 0..100 | Nil | 36 |
| 9 | Spituk | 10541±17.5 | 11 | 1.0 (Leh-Srinagar) | 1.0 | Nil | 1.2 |
| 10 | Spituk | 10580±37.2 | 10 | 0.800 (Leh-Srinagar) | 0.800 | Nil | 1.4 |
| 11 | Phyang | 11477±14.4 | 30 | 5 (Leh-Srinagar) | 5 | 5.1 (LPG bottling plant) | 20 |

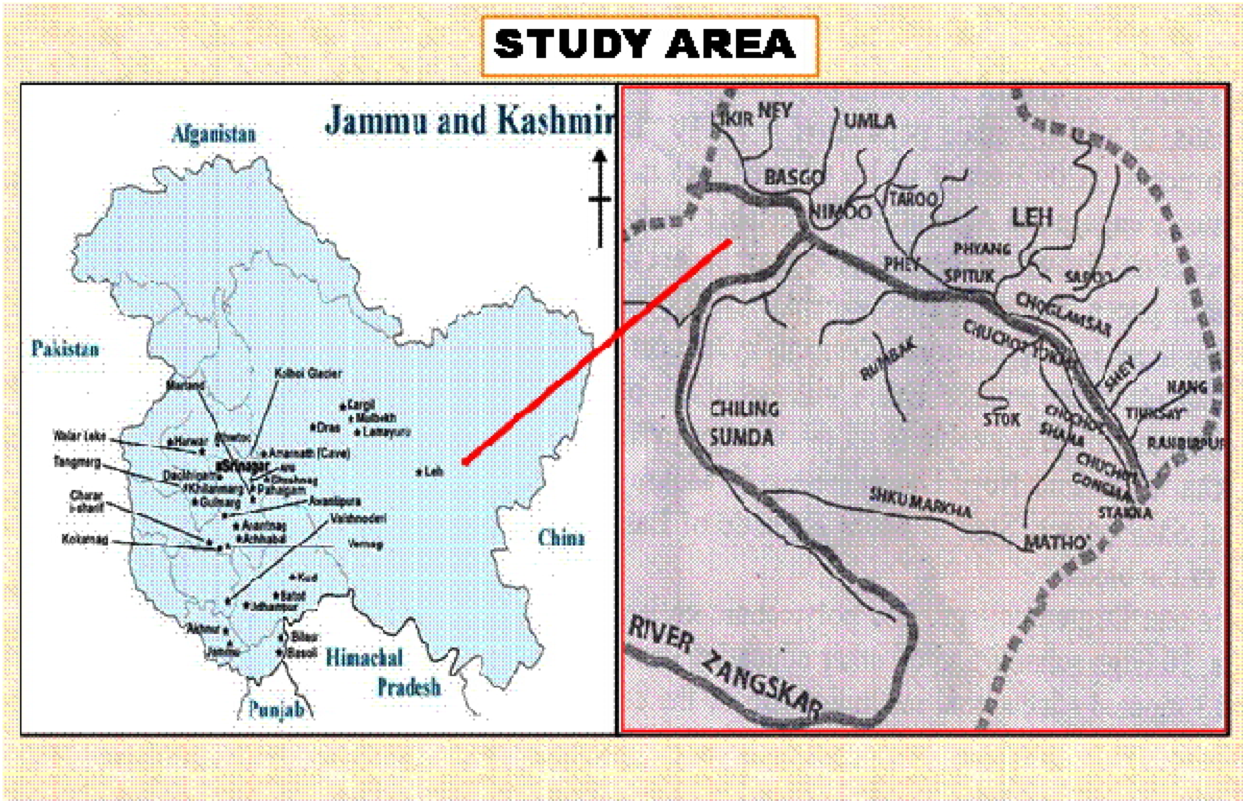


**Fig 5.1:** Map of study site

### 5.2.2 Water sample collection

All the water samples were collected from over a 70 kilometers of ranges where most of the population is residing. Total 66 samples from each irrigation and stagnant water (total eleven sites and six samples from each site) resources, while 42 (total seven sites and six samples from each site) water samples (1.0 ltr. volume) were collected from Indus River. The Samples were collected in acid pretreated plastic bottles (Table 5.1, 5.2, 5.3). Immediately 2-3 drops of pure toluene was added as a preservative and stored at $4^0$C for further analysis.

### 5.2.3 Chemical and reagents

For the laboratory analysis of various water quality parameters chemical and reagents were GR grade purchased from Merck Germany and some purchased from Sigma Aldrich United State of America were AR grade. Standards used in the estimation of heavy metals (Mg, Fe, Zn, Mn and B) that were single and multi-element, purchased from Merck, Germany.

**Table 5.3:** Study sites of Indus river water from cold desert high altitude microclimate

| Study Sites | Name of site | Altitude (ft. amsl) | Distance from Leh city (km.) | Distance from highway (km) | Distance from local market (km.) | Distance from industry (km.) | Distance from air port/air force station (km.) |
|---|---|---|---|---|---|---|---|
| 1 | Phey | 10524±32.8 | 25.5 | 3.5 (Leh-Manali) | 3.5 | 3.5 (LPG bottling plant) | 15.5 |
| 2 | Choglamsar | 10410±34.0 | 15.5 | 0.500 (Leh-Manali) | 0.500 | 0.80 (small steel firm ) | 26 |
| 3 | Ranbir pura | 10766±19.4 | 41 | 1.0 (Leh-Manali) | 1.0 | 0.80 (Concrete manufacturing unit) | 50 |
| 4 | Thiksey | 10670±24.0 | 36 | 1.0 (Leh-Manali) | 1.0 | 7 (Concrete manufacturing unit) | 45 |
| 5 | Shey | 10600±34.8 | 26.5 | 1.300 (Leh-Manali) | 1.300 | Nil | 36.5 |
| 6 | Spituk | 10450±11.4 | 11.5 | 1.5(Leh-Manali) | 1.5 | Nil | 1.7 |
| 7 | Nimu | 10300±25.5 | 45.5 | 1.100 (Leh-Manali) | 1.100 | Nil | 35.5 |

### 5.2.4 Laboratory methods

For the estimation of essential mineral elements, all the water samples were taken from the frost chamber and prepared for analysis as 50 ml of water sample was taken in 500 ml of conical flask and added 10 ml of 70% $HNO_3$ and kept at $80^0$C for 30 min, evaporated upto the 10 ml of sample, cooled and made volume 50 ml with Milli Q water and these samples were used for essential minerals analysis [APHA, 1989]. Essential minerals (Mg, Zn, Mn, Fe and B) were estimated by ICP-OES (Optima 7000 DV, Perkin Elmer, United States of America).

### 5.2.5 Statistical analysis

Data generated through the study were analyzed for mean and standard error (SE). Significant level ($P<0.05$) was generated among the different water resources (Indus river water, stagnant water (pond), irrigation water by one way ANOVA using the SPSS statistical software , 11.5 version, SPSS Inc. USA [SPSS, 1999].

## 5.3 Result

The total mean concentration of Fe, Mg, Mn, Zn and B in irrigation water were reported to be 0.360±0.04, 6.966±0.29, 0.058±0.006, 0.220±0.034 and 1.332±0.09 ppm, respectively, whereas the range differed from 0.053-1.712, 1.135-13.120, 0.025-0.219, 0.060-0.1724 and 0.011-2.730 ppm, respectively (Table 5.4).

**Table 5.4:** Essential minerals level (ppm) in irrigation water of cold desert high altitude

| Study Sites | Fe | Mg | Mn | Zn | B |
|---|---|---|---|---|---|
| 1 | $1.032^{c}$±0.16 | $9.695^{g}$±0.32 | $0.046^{b}$±0.002 | $0.879^{b}$±0.355 | $2.516^{e}$±0.13 |
| 2 | $0.267^{ab}$±0.01 | $6.184d^{e}$±0.64 | $0.032^{a}$±0.001 | $0.142^{a}$±0.015 | $1.635^{cd}$±0.15 |
| 3 | $0.161^{a}$±0.01 | $7.547^{ef}$±0.06 | $0.028^{b}$±0.001 | $0.108^{a}$±0.004 | $1.977^{d}$±0.04 |
| 4 | $0.295^{ab}$±0.05 | $8.006^{fg}$±0.29 | $0.031^{a}$±0.001 | $0.322^{a}$±0.130 | $1.958^{d}$±0.06 |
| 5 | $0.461^{b}$±0.10 | $8.715^{fg}$±0.35 | $0.036^{ab}$±0.003 | $0.117^{a}$±0.011 | $1.978^{d}$±0.06 |
| 6 | $0.263^{ab}$±0.04 | $8.451^{fg}$±0.10 | $0.033^{ab}$±0.002 | $0.442^{a}$±0.281 | $1.943^{d}$±0.02 |
| 7 | $0.233^{a}$±0.02 | $8.227^{fg}$±0.21 | $0.031^{a}$±0.001 | $0.172^{a}$±0.016 | $1.904^{d}$±0.05 |
| 8 | $0.206^{a}$±0.02 | $8.736^{fg}$±0.51 | $0.031^{a}$±0.001 | $0.146^{a}$±0.007 | $1.718^{cd}$±0.07 |
| 9 | $0.182^{a}$±0.02 | $7.985^{fg}$±0.15 | $0.030^{a}$±0.002 | $0.162^{a}$±0.005 | $1.393^{c}$±0.19 |
| 10 | $0.212^{a}$±0.04 | $7.716^{ef}$±0.07 | $0.034^{ab}$±0.002 | $0.145^{a}$±0.007 | $1.623^{cd}$±0.02 |
| 11 | $0.130^{a}$±0.02 | $9.038^{fg}$±0.41 | $0.038^{ab}$±0.005 | $0.208^{a}$±0.013 | $1.473^{c}$±0.06 |
| Mean | 0.360±0.04 | 6.966±0.29 | 0.058±0.006 | 0.220±0.034 | 1.332±0.09 |
| Range | 0.053-1.712 | 1.135-13.120 | 0.025-0.219 | 0.060-0.1724 | 0.011-2.730 |

Value (Mean±SE, N=6) bearing different superscripts differ significantly (P<0.05) between the row.

Statistical analysis revealed that, significantly (P<0.05) higher contents of Fe, Mg, Mn, Zn and B in irrigation water were reported to 1.032±0.16, 9.695±0.32, 0.046±0.002, 0.879±0.355, 2.516±0.13 ppm respectively at site 1, in all study sites (Table 5.4). The data regarding to the Fe, Mg, Mn, Zn and B concentrations in stagnant water were presented in Table 5.5 and the findings disclosed that, total average values of Fe, Mg, Mn, Zn and B were examined to be 0.403±0.05, 7.832±0.39, 0.055±0.005, 0.332±0.083 and1.346±0.10 ppm respectively in stagnant water (Table 5.5). The range differed from 0.020-1.884, 2.323-16.320, 0.027-0.209, 0.018-5.188 and 0.122-4.745 ppm respectively in stagnant water (Table 5.5). The findings of the study reported that, significantly (P<0.05) higher values of Fe, Mg, Mn, Zn and B were found at site 7 (1.085±0.27 ppm), site 2 (12.473±0.96 ppm), site 1 (0.189±0.010), site 3 (1.649±0.929) and at site 2 (2.559±0.21 ppm) respectively (Table 5.5).

**Table 5.5:** Essential minerals level (ppm) of stagnant water of cold desert high altitude

| Study sites | Fe | Mg | Mn | Zn | B |
|---|---|---|---|---|---|
| 1 | $0.559^{ab}$±0.20 | $10.038^{e}$±0.43 | $0.189^{d}$±0.010 | $0.224^{a}$±0.099 | $2.099^{ef}$±0.04 |
| 2 | $0.828^{bc}$±0.03 | $12.473^{f}$±0.96 | $0.050^{ab}$±0.004 | $0.650^{a}$±0.146 | $2.559^{f}$±0.21 |
| 3 | $0.511^{ab}$±0.34 | $4.319^{b}$±0.08 | $0.038^{ab}$±0.005 | $1.649^{b}$±0.929 | $0.706^{abc}$±0.22 |
| 4 | $0.255^{a}$±0.02 | $8.483^{cd}$±0.13 | $0.033^{a}$±0.002 | $0.187^{a}$±0.018 | $1.764^{de}$±0.04 |
| 5 | $0.216^{a}$±0.06 | $7.767^{c}$±0.24 | $0.031^{a}$±0.001 | $0.212^{a}$±0.066 | $1.753^{de}$±0.02 |
| 6 | $0.358^{a}$±0.04 | $11.911^{f}$±0.48 | $0.077^{c}$±0.006 | $0.153^{a}$±0.011 | $1.605^{de}$±0.07 |
| 7 | $1.085^{c}$±0.27 | $9.7298^{de}$±0.19 | $0.055^{b}$±0.010 | $0.167^{a}$±0.009 | $1.456^{cde}$±0.09 |
| 8 | $0.233^{a}$±0.00 | $8.686^{cd}$±0.48 | $0.040^{ab}$±0.001 | $0.310^{a}$±0.017 | $1.205^{bcd}$±0.07 |
| 9 | $0.276^{a}$±0.12 | $9.531^{de}$±0.71 | $0.047^{ab}$±0.006 | $0.15^{a}$±0.016 | $0.959^{abcd}$±0.23 |
| 10 | $0.148^{a}$±0.01 | $7.598^{c}$±0.10 | $0.045^{ab}$±0.004 | $0.167^{a}$±0.012 | $1.228^{cd}$±0.02 |
| 11 | $0.231^{a}$±0.01 | $3.063^{a}$±0.32 | $0.036^{ab}$±0.001 | $0.114^{a}$±0.024 | $1.478^{cde}$±0.82 |
| Mean | 0.403±0.05 | 7.832±0.39 | 0.055±0.005 | 0.332±0.083 | 1.346±0.10 |
| Range | 0.020-1.884 | 2.323-16.320 | 0.027-0.209 | 0.018-5.188 | 0.122-4.745 |

Value (Mean±SE, N=6) bearing different superscripts differ significantly (P<0.05) between the row.

The essential minerals (Fe, Mg, Mn, Zn and B) in Indus river water were differed widely and observed to be ranged from 0.087-3.005, 3.593-11.00, 0.030-0.129, 0.065-6.718 and 0.323-2.457 ppm respectively (Table 5.6). Whereas, total average concentrations were reported to 0.581±0.11, 8.181±0.25, 0.047±0.004, 0.341±0.188 and 1.467±0.11 ppm respectively Indus river water (Table 5.6). One way ANOVA analysis revealed that, significantly (P<0.05) higher level of Fe, Mg, Mn, Zn and B were reported at site 1 (1.424±0.27 ppm), site 7 (9.431±0.70 ppm), site 1 (0.088±0.005 ppm), site 4 (1.462±1.314 ppm) and site 2 (2.117±0.10 ppm) respectively in Indus river water (Table 5.6).

**Table 5.6:** Essential minerals concentration (ppm) in river (Indus) water from cold desert high altitude region

| Study sites | Fe | Mg | Mn | Zn | B |
|---|---|---|---|---|---|
| 1 | $1.424^{b}$±0.27 | $6.6594^{a}$±0.77 | $0.088^{b}$±0.005 | $0.139^{a}$±0.027 | $1.485^{c}$±0.19 |
| 2 | $0.845^{ab}$±0.43 | $8.803^{b}$±0.26 | $0.056^{a}$±0.018 | $0.110^{a}$±0.016 | $2.117^{d}$±0.10 |
| 3 | $0.469^{a}$±0.04 | $8.018^{ab}$±0.45 | $0.038^{a}$±0.001 | $0.118^{a}$±0.014 | $1.959^{d}$±0.18 |
| 4 | $0.513^{a}$±0.17 | $8.541^{ab}$±0.96 | $0.047^{a}$±0.011 | $1.462^{a}$±1.314 | $1.914^{d}$±0.17 |
| 5 | $0.215^{a}$±0.01 | $7.639^{ab}$±0.47 | $0.036^{a}$±0.000 | $0.237^{a}$±0.019 | $1.192^{bc}$±0.08 |
| 6 | $0.106^{a}$±0.01 | $8.051^{ab}$±0.38 | $0.033^{a}$±0.002 | $0.202^{a}$±0.011 | $1.078^{b}$±0.11 |
| 7 | $0.445^{a}$±0.28 | $9.431^{b}$±0.70 | $0.032^{a}$±0.001 | $0.118^{a}$±0.007 | $0.397^{a}$±0.03 |
| Mean | 0.581±0.11 | 8.181±0.25 | 0.047±0.004 | 0.341±0.188 | 1.467±0.11 |
| Range | 0.087-3.005 | 3.593-11.00 | 0.030-0.129 | 0.065-6.718 | 0.323-2.457 |

Value (Mean±SE, N=6) bearing different superscripts differ significantly ($P<0.05$) between the row.

## 5.4 Discussion

### 5.4.1 Iron (Fe)

Fe is essential trace element both for human and plants, found in natural fresh waters at levels ranging from 0.5 to 50 ppm, unpolluted surface water 0.001-0.5 ppm and sea water approximately 0.002 ppm. Iron is dissolved from underlying rocks and soils then come to the water resources whether river water, ground water or surface water. WHO [2004] standards for Drinking water suggested that concentrations of iron >1.0 ppm would markedly impair the potability of the water. Desirable level of Fe is 0.3 ppm and maximum permissible limit is 1.0 ppm in drinking water for humans [BIS, 2005], the our experimental results about the Fe are under the permissible limit so there is no health risk for humans. The desired level of Fe for livestock is <0.2 ppm and maximum upper limit Fe for livestock is 0.4 ppm further recommended maximum concentration of iron for livestock drinking water 0.3ppm [NRC, 1998], our present results described that the level of Fe in various water ecosystems is in optimum level except Indus river water, in which level is little bit high according to the livestock water quality guidelines so our recommendation regarding the Fe level in drinking water for the animals and human being, there is little bit risk for the animals, otherwise it is good for both animals and human beings. As per the irrigation water quality is concerned, it is again sound for the irrigations purposes to various crops grown in this region.

Recommended limits of Fe in reclaimed water for irrigation, is 5.0 ppm in long term use and 20 ppm in short term use [Rowe and Abdel-Magid, 1995], further it was reported that the $<0.3$ ppm in irrigation water causes no problem, 0.3-5.0 ppm increases problem and $>5.0$ ppm causes severe problems to crop plants. Our present results disclosed that the Fe level in studied water sources is optimum for irrigation purposes to various crops at this region. Since most soils are naturally iron rich, its concentration in the soil solution is determined primarily by soil pH and soil aeration, which determine the oxidation state and thus solubility of iron. Therefore, the iron content of irrigation water has a negligible effect on the iron concentration in soil water, except in the case of soils with low natural iron content.

**5.4.2 Magnesium (Mg)**

Magnesium is washed from rocks and subsequently ends up in water; the most common source of magnesium in groundwater, river water glacier water is through the erosion of rocks, such as limestone and dolomite and minerals, such as magnetite. Mg in soil is derived from minerals biotite, phlogopite, hornblende, olivine and serpentine, in arid region substantial amounts of mineral epsomite may be present and in calcareous soils Mg may found as dolomite; Mg in soil solutions ranges from 50-120 ppm [Prasad, 2007]. The mean values of Mg in irrigation water is reported to $6.966\pm0.29$ ppm while in stagnant water (ponds) $7.832\pm0.39$ ppm and in river water it was $8.181\pm0.25$ ppm, the desired level of Mg in drinking water ($<50$ ppm) maximum permissible limit 300 ppm prescribed by [BIS, 1998] for the livestock, therefore, Mg concentration in our present study are much below the maximum permissible limit so there is no problem for animals health at this region. As the waters from different resources of this microclimate is concerned for drinking purpose to human beings, the investigated results shown very low level of Mg according to BIS, [1999] (100 ppm); ICMR, [1975] (200 ppm) and WHO, [2004] (150 ppm) standards, then there is no health conciliation when water utilized for the drinking purpose from different resources in this microclimate. Low level of Mg in various water resources in this region may be due to the low solubility of magnesium salts in water because of alkaline nature of water. Mg is most essential nutrient for crop plant growth and development if it comes through the irrigation water from the available resources in the prevailing ecosystem but there is no any guideline for Mg standard for irrigation water.

### 5.4.3 Manganese (Mn)

Manganese is an essential element for humans and animals and is least toxic element [WHO, 1993]. Mn is an element of low toxicity having considerable biological significance and one of the more biogeochemical and active transition metal in aquatic environment [Evans, 1977], inhalation of high dose of Mn leads to death of both human and animals. Our present study revealed that, manganese concentrations in water resources collected from the cold arid region are reported below the recommended permissible limit so this decreased level of Mn is safe for the human and animals. For irrigation the Mn concentration should not exceed 2.0 ppm [USEPA, 1999] and health based guideline value is 0.4 ppm [WHO, 2004]. The health-based value of 0.4 ppm for manganese is higher than this acceptability threshold of 0.1 ppm; concentrations below 0.1 ppm are usually acceptable to consumers. Maximum desirable limit of Mn is 0.1 ppm for the drinking purpose to human being and permissible limit 0.3 ppm [BIS, 2005] beyond this limit taste/appearance are affected, has adverse effect on domestic uses and water supply structures. There have been epidemiological studies though, that reported the adverse neurological effects following extended exposure to very high levels in drinking water [WHO, 2011]. As it was reported that the Mn concentration less than the 10 ppm has no effect on animal health, 10-50 ppm causes adverse chronic effects such as weight loss due to in appearence may occur while >50 ppm causes adverse chronic effects such as weight loss and anemia in livestocks [DWAF, 1996]. For the irrigation it was reported that the Mn concentration <0.2 ppm have no effect on crop plants while the content >0.2 ppm having severe effect on crop plants.

### 5.4.4 Zinc (Zn)

Zn standard for drinking water is 5 ppm for the human being [BIS, 2005] and Permissible limit in the absence of alternate source [BIS, 2005] while the safe limit for Zn concentration in irrigation water ranges from 2-5 ppm [USEPA, 1999]. CCME [2005] Livestock Guidelines for zinc is 50 ppm. Although levels of zinc in surface water and groundwater normally do not exceed 0.01 and 0.05 ppm, respectively [WHO, 2011], concentrations in tap water can be much higher as a result of dissolution of zinc from pipes [WHO, 2011]. However, drinking-water containing zinc at levels above 3 ppm may not be acceptable to consumers. So the present study results revealed that the Zn levels in all study sites from Indus River water, Irrigation and stagnant waters were found to be below the permissible limit and have no health risk to the crop plant as well as to human and animals existed all over in the study sites. Zinc poisoning in cattle, sheep and pigs probably occurs less frequently due to these species tolerate high doses of this mineral in diet [NRC, 1996; Radostits et al., 2002]. Zinc is very essential micronutrient in human body but at very high concentration it may cause some poisonous effects [Kothny, 1973]. Zn is an essential element for plant food and exists in water and soil as an organic complexes and inorganic salts, zinc is required for the growth, sexual development, wound healing, infection fighting, sense of taste, night vision in humans [WHO, 1993]. Zinc toxicity also increases with increase in temperature and decrease of dissolved oxygen.

### 5.4.5 Boron (B)

The B concentration ranges in drinking water between 0.1 and 0.3 ppm. Boron naturally occurring in groundwater, from decaying plant materials, industrial pollutants and from agricultural runoff water. Boron compounds are used in the manufacturing of glass, soaps and detergents and as flame retardants. Generally the population obtained the greatest amount of B through food intake, as it is naturally found in many edible plants but its presence in surface water is frequently a consequence of discharge from the treated sewage effluent, in which it arises from use in some detergents, to surface waters, concentrations vary widely and depend on the surrounding geology and wastewater discharges. Boron containing minerals in soils are tourmaline, anexite, ulexite, colemanite and kernite; tourmaniteis the most important boron containing minerals are quite resistant to weathering, most plant available B comes from the B adsorbed and precipitated onto the surface of soil particles or from the decomposition of soil organic matter [Prasad, 2007].

The desirable level of B content in drinking water for the livestock is <5ppm [NRC, 1980] and maximum permissible limit (MPL) is >5ppm [EPA, 1997], the present study revealed that the B in all studied aquatic ecosystems is below the permissible limit as per the B is concerned for the animal health and its observed quantity is optimum for drinking purpose to livestock. Boron is trace essential element for the crop plants it is more dynamic element if supplied with the irrigation water, its toxicity occurs with the uptake of boron from the soil solution; tend to accumulate in the leaves until it become toxic to the leaf tissue and results in the death of the plant. In arid regions, boron is considered the most harmful element in irrigation water. For some crops 0.2 ppm boron in water is essential, 1 to 2 ppm may be toxic. B in irrigation water <10 ppm is not suitable for any crop plant irrigation [Reddy, 2000]. Boron toxicity can affect nearly all crops but in case of salinity, there is a wide range of tolerance among crops. Boron concentrations determined in our study will not pose any effect to the crops plants if irrigated with water from these resources, further B level will not affect to health of human being and further health and performance of livestock; tolerance of livestock is rather low as compared to human beings and affected at B concentration (>5ppm) in drinking water. Higher level of B in various water resources may be due to the arid environment, alkaline nature of soil and water where B availability is rather than more as it was reported that B may be a problem in arid and semi arid areas [Gupta, 1979]. Other reasons may be, surface water rarely contains enough boron to be toxic but well water or springs occasionally contain toxic amounts, especially near geothermal areas and earthquake faults. Our recommendation, water resources used for various purposes like drinking to livestock and humans and for irrigation to different crops is suitable and safe as per their health and performance is concerned under the present determined level of boron.

## 5.5 Conclusion

Our study in cold arid region indicated that, various water resources having essential minerals content is lower than the optimum level that is required by the plant, animals and human beings so it is recommended that all the studied mineral elements need to be supplemented with other resources. The present study disclosed that all studied essential mineral nutrients are observed to be below the maximum permissible limit (MPL) except the Fe which was observed above the MPL as per the animal tolerance is concerned. Apart from this, water from various resources has quite good amount of all studied essential mineral nutrients so it may provide extra mineral nutrients supplement to the plant and animals other than the from feed and fodders. Further, water resources from cold desert region are considered quite good for irrigation purposes to various crops as their mineral nutrients essentiality is concerned. However, further studies are warranted as regards its use for drinking purposes to human and animals.

# CHAPTER VI

## To know essential minerals status and evaluate mineral interrelationships in soil, fodders and animals of cold desert high altitude region

**Abstract**

However the interrelationship of soil essential mineral nutrients with their contents in fodders grown here is not well established. The hypothesis of soil–plant–animal interrelationship evolved a synchronized understanding of how meticulous sequence of events may lead to imbalances in essential minerals of a feed or fodder for livestock. Therefore the present study was conducted to elucidate the interrelationship of essential minerals of soil with fodders crop plants grown in cold arid region of Ladakh. For the study, agriculture soil, *Medicago sativa* L., *Triticum aestivum* L. straw and serum samples of native sheep and goats samples were collected and samples were analyzed for essential minerals viz. iron Fe, Mg,Mn, Zn, Cu, Co and B. The finding revealed that total mean concentrations of Fe, Mg, Mn, Zn, Cu, Co and B in agriculture soil were examined to 48475.40±1208, 2424.02±130, 637.49±16.24, 86.67±2.85, 38.80±1.22, 19.947±0.41 and 80.13±3.51 mg/kg on dry matter basis (DM), respectively. Whereas, total mean level of these mineral elements in *Medicago sativa* L., *Triticum aestivum* L. straw were observed to 183.23±27.5, 2598.78±94.3, 61.71±3.4, 51.09±3.42, 29.93±2.30, 0.497±0.02 and 17.452±1.72 ppm; 126.28±9.1, 1516.95±68.4, 67.66±4.1, 36.01±1.95, 15.06±0.53, 0.622±0.03 and 11.497 ±0.96 ppm DM, respectively. Further, total average concentration of Fe, Mg, Mn, Zn, Cu, Co and B in serum samples of native sheep and goats were reported to 13.62±1.6, 25.43±0.74, 7.69±0.3, 1.74±0.12, 0.407±0.04, 2.796±0.325 and 6.01±0.59 ppm; 11.54±2.50, 24.01±1.28, 6.84±0.55, 0.421±0.07, 3.328±0.62, 1.48±0.13 and 6.23±0.92 ppm respectively. Pearson correlation coefficient ($r^2$) analysis unveiled that, Mg level in soil was significantly ($P<0.01$) positively ($r^2$=0.420**) correlated with their level in *Medicago sativa* L. and significantly ($P<0.05$) negatively ($r^2$=-0.356*); level of Zn in *Triticum aestivum* L. straw was significantly ($P<0.05$) negatively ($r^2$=-0.368*) correlated with their level in native sheep; Mn in wheat straw significantly ($P<0.01$) negatively ($r^2$=0.478**) correlated with their level in goat and also Fe and Co concentrations in *Medicago sativa* L. were found to be significantly ($P<0.01$) positively ($r^2$=0.394*; 0.394*) correlated with their levels in serum samples of goat. The Fe content in soil was examined to significantly ($P<0.05$) negatively ($r^2$=-0.213*) correlated with their content in sheep. The findings predicted that, availability and the dynamics of mineral elements in agriculture soil are highly affected by the existing harsh climatic conditions at this region. Therefore the care must be taken during mineral mixture formulation or any feed supplement at

this region for the small and large animals because fodders from this region have different level of essential minerals with different responses to the each type of mineral element.

**Key words:** Essential mineral nutrients, Interrelationship, cold desert, high altitude, microclimate

## 6.1 Introduction

There is complex relationship between soil, plant and animals due to specific characteristics of the plants and interaction between different minerals [Bhat et al., 2011], in nature a perfect succession of nutrients movement from soil to plants and from plants to animals and reverse to soils is maintained [Bhat et al., 2011]. In India where dietary concentrations of fodders fed to the animals are unknown and highly affected due to availability, season, location, forage species and animals potential so it is important to determine mineral concentrations in animals' region wise to estimate needs of livestock. There is greater degree of uncertainty in the mineral nutrients requirement of animals depending upon age, breed and level of production, dietary antagonist, animal adaptation and interrelationship with other nutrients. In our country, supply of essential minerals often comes largely from pasture herbage, hays and straw based diets which are found to be in border lines or deficient. Moreover, these feed and fodders are high in silicate, oxalates and tannins which interfere with the utilization of these mineral nutrients. The essential minerals status of fodder may be altered by plant species, stage of harvesting, season of the year, fertilization application rate and soil type and soil pH.

The soil is the primary source of trace elements for plants, animals and humans. Trace elements are those nutrients required in extremely small quantities (<100 ppm) in plant dry weight). They are essential for the correct functioning of many plant, animal and human biological systems. Micronutrient malnutrition is a growing concern in the developing and developed world. The mineral deficiency can be corrected by supplementation which can save huge economic losses. It results in mental retardations, impairments of the immune system and overall poor health of human and animals. Under Indian condition which is tropical the mineral deficiency disease are quite common and is mainly due to non availability of balanced diet or deficiency of minerals in soil and fodder.

Heavy rainfall, leaching of soils, making them deficient in plant minerals [Pfonder, 1971]. In this country, the supply of macro-minerals often comes largely from pasture herbage, hays and straw based diets which are found to be border line to deficient in macro-minerals.

Moreover, these are high in silicate, oxalates and tannins which interfere with the utilization of these nutrients [Khan et al., 1999]. The macro-mineral status of fodders may be altered by plant species, stage of harvesting, season of the year, fertilization application rate, soil type and soil pH [McDowell, 1997]. Mineral nutrients (major and minor) are very important for several metabolic functions and their deficiency impairs production and reproduction. The availability of minerals to cattle depends upon the production system, feeding practices and environment [Singh and Bohra, 2005]. Among the different environmental factors, soil plays a vital role in cattle production and health because cattle obtain their nutrient needs from the feed and fodder, which in turn obtain nutrients from the soil. The role of soil and nutritional quality of plants with respect to the health and production of livestock is very important and varies from place to place [Abdel Rehman et al., 1998]. Factors that influence the mineral composition of plants vary greatly depending on the location where they are grown. In general, the chemical composition of the plant is influenced to a greater extent by inherent soil properties. For example, it has been reported that red clover grown in a calcareous soil contained more calcium, phosphorus and sulfur than the red clover grown in a loamy soil [Beeson and Matrone, 1976]. It is important to determine the mineral concentrations of soils and fodders to estimate the mineral needs of ruminants [Pereira et al., 1997]. The mineral profile of soil, plant and animals has been reported in plain regions [Baruah et al., 2000; Sharma et al., 2003] however, it has not been studied in detail in subtropical hill ecosystem. Therefore, the purpose of the present study was to estimate essential minerals content of soil, plant and dairy cattle and to establish the soil-plant-animal continuum in subtropical hilly area. Plants are an important component of ecosystems as they transfer elements from abiotic into biotic environments. The primary sources of elements from the environment to plants are air, water and soil. Plants grown in a polluted area may accumulate a much higher than normal amount of trace elements. The trace elements in the soil play a dual role in agriculture. Some trace elements are essentially required for the healthy growth of plants, as well as to contribute as essential minerals to human beings. However, some trace elements are not only toxic for plants but also pose a health risk to humans [Haluschak et al., 1998]. Zinc is also a critical micronutrient required for structural and functional integrity of biological membranes and for detoxification of highly aggressive free radicals [Cakmak, 2000]. Any alteration in Zn homeostasis or any decrease in Zn concentration of human body will, therefore, result in number of cellular disturbances and impairments such as immune dysfunctions and high susceptibility to infectious diseases, retardation of mental development and stunted growth of children [Black, 2003]. Zinc deficiency, for example, represents a major cause of child death in the world and is a widespread global issue. Nutritional inadequacies often limit animal production in many countries of the world and in many regions ruminant livestock production is often restricted by mineral deficiencies, toxicities and imbalances [McDowell, 1992; Rojas et al., 1993]. Livestock often do not receive mineral supplement and must depend upon fodders to meet their nutritional requirements. However, forage rarely can completely satisfy each of the mineral requirements for grazing animals [McDowell, 1997].

Boron is important for early growth and cell wall strength in addition to its important role in pollen formation, survival and viability. Some trace elements are essential nutrients for plant growth and often also for food and feed quality because the primary route for their intake by humans and animals is plants. These trace elements might better be called micronutrients. Included in this group are boron, chlorine, copper, iron, manganese, molybdenum and zinc. The importance of other trace elements found in plants but, as yet without any recognized function, relates to their role in animal nutrition. Their presence in plants would appear to have allowed animals to use them in their metabolic processes often in enzyme systems. Among such elements are cobalt, chromium, fluorine, iodine, nickel and selenium. Animals having developed a dependency on these trace elements, they too could be described as micronutrients. More elements have been shown to be essential for animals than for plants. Thus it is essential that micronutrients, whether required by plants or animals, are present in sufficient plant-available concentrations in the soil to ensure optimum productivity. The trace element content of a soil depends initially on the parent material from which it was formed [Mason and Moore, 1982] but subsequent leaching and nutrient cycling through plants and animal excreta creates both depletion and enrichment often in specific soil horizons. The soil profile can also gain elements through deposited dust, important in areas prone to dust storms, by adsorption from water draining into a soil from elsewhere and by pollution due to human activity. So the keeping above problem in the mind, we design the present study with the objectives that will determined to understand dynamics and their cycling of trace mineral nutrients through the soil, plant and animals. Keeping the above problems in mind, the present study was designed to establish an interrelationship for different essential mineral nutrients in soil, fodders and animals in order to suggest feeding supplementation for this area to specific mineral mixture and further it will help to understand the soil mineral dynamics and nature of soil, mineral absorption potential of plants, mineral interaction in plants at this cold arid environment.

## 6.2 Material and methods

### 6.2.1 Location and study conditions

The study was conducted in Leh-Ladakh (a high altitude Cold desert in India) at 3500 m. amsl, lying between 32°15'36 N and 75°15'80 E. The experiment was carried out during October to February months (winter season) and environmental temperature during the experimental period ranged from -26°C in the month of January to 19°C in the month of October. Average daily temperature and relative humidity during the experimental period was -1.76°C and 44%, respectively.

### 6.2.2 Soil sampling, processing and digestion

Random soil sampling was done due to the very small size of plots in this region. A total of 54 composite agricultural soil samples (06 from each sampling site, total site: 09) were collected. Ten sampling points were selected at each sampling site (100 × 20 m size); thereafter one soil sample was collected from up to 15 cm soil depth (plough layer) by quartering method from each sampling point. All the soil samples were air dried at room temperature, sieved with <2.0mm test sieve and further it was grinded in stainless steel pestle and mortar and sieved with 200µm of test sieve. Further soil samples were digested on dry matter basis by using metal grade HF (hydrofluoric acid), nitric acid and hydrochloric acid, samples were digested on 42 blocks Automated Hot Bock digestion system (Questron Technologies Inc, Canada). These all samples were analyzed for the estimation of all essential mineral nutrients and heavy metals.

### 6.2.3 Plant sampling, processing and digestion

Lucerne or alfalfa (*Medicago sativa* L.) and wheat straw, (*Triticum aestivum* L.) crop plant samples were collected from targeted area, alfalfa fresh leaves sample were collected on maturity of the crop plants while the whole plant above the surface was collected in case of wheat straw. Nine sampling sites were selected for the study, in which 15 small samples were collected from each sampling site and mixed and then required quantity of plant sample was taken by quartering method so the six plant samples were taken for the analysis. Then all the air dried plant samples were oven dried at $65^0$C for the 12 hours and then grinded in stainless steel heavy duty plant sample grinder to obtain homogeneous sample size. All the plant samples were digested on dry matter basis, plant samples were digested by using metal grade nitric acid ($HNO_3$), hydrogen peroxide ($H_2O_2$) hydrochloric acid (HCl), samples were digested on 42 blocks Automated Hot Bock digestion system (Questron Technologies Inc., Canada). These all samples were analyzed for the estimation of all essential mineral nutrients.

### 6.2.4 Sheep & goat blood sampling, processing and digestion

Total ninety blood samples were collected from native female Changthangi sheep (10 samples from each nine site) and sixty samples from native female Changthangi goat (10 samples from each six village). About 5 ml of blood was collected from jugular vein in the vials, kept the samples at $4^0$C for overnight and then centrifuge it at 6000 rpm for 5 min, serum was collected in separate storage vials and stored at -$80^0$C. All the serum samples were digested on mass to weight basis, samples were digested by using metal grade nitric acid ($HNO_3$), perchloric acid ($HClO_4$) hydrochloric acid (HCl), samples were digested on 42 blocks Automated Hot Bock digestion system (Questron Technologies Inc, Canada).

### 6.2.5 Chemical and reagents

For the analysis of various essential mineral nutrients in soil, plant and animal blood serum, metal grade digestion acids ($HNO_3$, $H_2O_2$, HCl, HF and $HClO_4$) purchased from Merck, Germany and Sigma Aldrich, United State of America were AR grade. For the estimation of essential mineral elements and various heavy metals in soil, plant and serum samples, single and multi-element standards were used and these were purchased from Merck, Germany. Various essential mineral elements were estimated in soil, plant and animal's serum samples by Inductively Coupled Plasma-Optical Emission Spectroscopy (Optima 7000 DV, Perkin Elmer, United State of America).

### 6.2.6 Statistical analysis

Data generated through the study were analyzed for mean and standard error (SE) by one way ANOVA using the SPSS computer programme (17.0 versions). Significance level ($P<0.05$) was generated among the different mean values by Duncan's multiple range test (DMRT) among different sampling locations. Pearson correlation coefficient (r) analysis was done in soil, plant and animals for the various essential mineral nutrients by using SPSS computer programme.

## 6.3 Result

### 6.3.1 Level of essential minerals in agriculture soil

The total average concentration of essential minerals in agriculture soil were estimated to be 48475.4±1208 mg/kg (Fe), 637.495±16.24 mg/kg (Mn), 86.668±2.85 (Zn), 80.133±3.51 mg/kg B, 2424.019±130 mg/kg (Mg), 38.80±1.22 mg/kg (Cu) and 19.947±0.41 mg/kg of Co (Table 6.1). Whereas the Fe, Mn, Zn, B, Mg, Cu and Co concentrations varied from 33300-68510, 445.47-909.70, 10.46-137.8, 34.98-126.1, 33300-68510, 16.57-78.4 and 11.67- 36.53 mg/kg respectively (Table 6.1). Significantly ($P<0.05$) higher concentrations of Fe, Mn, Zn, B, Mg, Cu and Co were observed at site 9 (58976.4±338 mg/kg), site 9 (816.356±34.33 mg/kg), site 2 (123.288±7.21 mg/kg) and site 2 (113.23±7.00 mg/kg), site 2 (4068.60 mg/kg), site 1 (52.07±0.86 mg/kg) and site 1 (26.44 ±1.43 mg/kg) respectively in agriculture soil (Table 6.1).

### 6.3.2 Level of essential mineral nutrients in forages

Fe, Mg, Mn, Zn, B, Co and Co contents in *Triticum aestivum* L. straw samples were ranged from 16.30-236, 897.9-2589, 39.78-194, 9.56-70.29, 10.78-27.42, 0.371-1.203 and 0.651-26.090 ppm respectively while the total mean concentrations were examined to be 126.28±9.1, 1516.95±68.4, 67.66±4.1, 36.01±1.95, 15.06±0.53, 0.622±0.03 and 11.497±0.96 ppm respectively (Table 6.2). Fe, Mg, Mn, Zn, B, Co and Cu levels in *Medicago sativa* L. samples were ranged from 16.26-1342, 1709-5748, 21.40-161.3, 21.56-119.2, 10.76-76.3, 0.217–1.195 and 5.345–61.710 ppm, whereas the total mean concentrations were determined to be 183.23±27.5, 2598.78±94.3, 61.71±3.4, 51.09±3.42, 29.93±2.30, 0.497±0.02 and 17.452±1.72 ppm respectively in *Medicago sativa* L. (Table 6.3).

### 6.3.3 Level of essential mineral nutrients in serum samples of Sheep and Goat

From the present study it was reported that, the levels of Fe, Mg, Mn, Zn, Co, Cu and B were examined to be 13.62±1.6, 25.43±0.74, 7.69±0.3, 1.74±0.12, 0.407±0.04, 2.796±0.325 and 6.01±0.59 ppm respectively in native sheep, whereas their range varied from 0.1-87.5, 7.0-40.7, 0.3-15.8, 0.7-8.3, 0.100-1.519, 0.456-10.520 and 0.1-38.7 ppm respectively (Table 6.4).

**Table 6.1:** Certain essential mineral concentration (mg/kg) in agriculture soil from cold desert high altitude region

| Study sites | Fe | Mg | Mn | Zn | Cu | Co | B |
|---|---|---|---|---|---|---|---|
| 1 | 46140.00[bc] ±1109 | 2103.20[a] ±43.90 | 587.33[bc] ±15.90 | 91.06[ab] ±4.15 | 52.07[h] ±0.86 | 26.44[k] ±1.43 | 99.29[ef] ±1.68 |
| 2 | 50297.20[c] ±3229.00 | 4068.60[c] ±503.00 | 668.38[c] ±32.70 | 123.29[c] ±7.21 | 43.20[def] ±1.25 | 20.68[def] ±0.51 | 113.23[g] ±7.00 |
| 3 | 38476.00[a] ±921.00 | 1765.60[a] ±255.00 | 495.79[a] ±20.06 | 81.00[ab] ±9.32 | 50.70[gh] ±3.65 | 23.64[ij] ±1.21 | 87.28[de] ±2.51 |
| 4 | 49114.80[c] ±1457.00 | 3518.40[bc] ±723.00 | 636.35[c] ±22.40 | 88.81[ab] ±4.50 | 39.72[d] ±2.48 | 18.23[ab] ±0.87 | 103.88[fg] ±1.76 |
| 5 | 46905.60[bc] ±1030.00 | 2650.2[ab] ±258.00 | 602.79[bc] ±8.87 | 86.86[ab] ±1.47 | 49.54[ef] ±1.69 | 22.49[ghi] ±0.64 | 87.65[de] ±5.11 |
| 6 | 41297.60[ab] ±1163.00 | 2474.20[a] ±146.00 | 530.23[ab] ±2.38 | 67.95[a] ±3.49 | 45.45[def] ±1.15 | 19.59[cd] ±0.30 | 96.16[ef] ±7.58 |
| 7 | 35093.80[a] ±762.00 | 1858.20[a] ±118.00 | 502.67[a] ±13.21 | 72.28[ab] ±17.80 | 38.37[d] ±1.07 | 19.06[bc] ±0.62 | 79.67[cd] ±6.55 |
| 8 | 57303.40[de] ±3950.00 | 2405.40[a] ±222.00 | 798.31[d] ±42.52 | 91.93[ab] ±8.40 | 30.86[c] ±1.13 | 15.20[a] ±0.99 | 69.49[bc] ±2.98 |
| 9 | 58976.40[e] ±338.00 | 2160.80[a] ±102.00 | 816.36[d] ±34.33 | 93.79[b] ±5.19 | 27.13[bc] ±1.87 | 19.70[cd] ±1.10 | 40.14[a] ±1.17 |
| Mean | 48475.40 ±1208.00 | 2424.02 ±130.00 | 637.49 ±16.24 | 86.67 ±2.85 | 38.80 ±1.22 | 19.947 ±0.41 | 80.13 ±3.51 |
| Range | 33300-68510 | 1234-5379 | 445.47-909.70 | 10.46-137.80 | 16.57-78.4 | 11.67-36.53 | 34.98-126.10 |
| *Critical level | <20 | <120 | <5 | <1.5 | 0.20 | 0.1 | <0.5 |

Data (N = 6) were analyzed for Mean±SE (Standard Error).

Data presented in a column with different superscript ([a,b,c,d,e]) differed significantly ($P<0.05$).

**Critical level, Fe, Mn, Zn & B [Olsen and Carlson, 1950]; [Jackson, 1973]; Mg [McDowell et al., 1984]; Co [McDowell et al., 1983]

**Table 6.2:** Certain essential mineral concentration (ppm) in wheat straw (*Triticum aestivum* L.) from cold desert high altitude region

| Study sites | Fe | Mg | Mn | Zn | B | Co | Cu |
|---|---|---|---|---|---|---|---|
| 1 | $101.27^{ab}$ ±4.6 | $1476.6^{cd}$ ±140 | $74.78^{ab}$ ±7.6 | $36.42^{b}$ ±6.59 | $17.01^{bc}$ ±0.65 | $0.769^{d}$ ±0.03 | $7.391^{ab}$ ±1.22 |
| 2 | $195.09^{c}$ ±5.1 | $1114.1^{b}$ ±75.3 | $42.13^{a}$ ±1.2 | $39.83^{b}$ ±0.58 | $14.81^{ab}$ ±0.51 | $0.640^{bcd}$ ±0.03 | $13.488^{cd}$ ±0.31 |
| 3 | $77.66^{ab}$ ±2.1 | $1172.8^{abc}$ ±45.4 | $76.15^{ab}$ ±2.5 | $12.42^{a}$ ±1.20 | $19.30^{c}$ ±2.50 | $0.697^{cd}$ ±0.05 | $16.280^{d}$ ±2.43 |
| 4 | $197.19^{c}$ ±6.3 | $1394.3^{cde}$ ±168 | $85.35^{b}$ ±11.5 | $31.04^{b}$ ±1.77 | $14.02^{ab}$ ±1.51 | $0.978^{e}$ ±0.11 | $22.922^{e}$ ±1.11 |
| 5 | $210.80^{c}$ ±9.7 | $1057.72^{a}$ ±66.2 | $69.21^{ab}$ ±3.9 | $39.67^{b}$ ±1.00 | $12.38^{a}$ ±0.53 | $0.447^{ab}$ ±0.01 | $14.278^{cd}$ ±0.96 |
| 6 | $72.19^{ab}$ ±22.8 | $1474.6^{cd}$ ±91.9 | $41.98^{a}$ ±0.9 | $34.23^{b}$ ±1.34 | $13.33^{a}$ ±0.49 | $0.410^{a}$ ±0.02 | $5.328^{a}$ ±0.34 |
| 7 | $106.82^{b}$ ±4.8 | $1592^{d}$ ±56.4 | $80.66^{b}$ ±2.7 | $33.77^{b}$ ±1.06 | $12.00^{a}$ ±0.39 | $0.457^{b}$ ±0.01 | $5.809^{ab}$ ±2.09 |
| 8 | $110.05^{b}$ ±25.1 | $2039.6^{e}$ ±160 | $80.26^{b}$ ±28.8 | $60.36^{c}$ ±4.49 | $13.40^{a}$ ±0.82 | $0.685^{cd}$ ±0.14 | $10.789^{bc}$ ±3.02 |
| 9 | $65.44^{a}$ ±1.7 | $2330.8^{e}$ ±53.8 | $58.44^{ab}$ ±1.1 | $36.31^{b}$ ±1.22 | $19.27^{c}$ ±1.01 | $0.515^{abc}$ ±0.02 | $7.191^{ab}$ ±0.36 |
| Mean | 126.28 ±9.1 | 1516.95 ±68.4 | 67.66 ±4.1 | 36.01 ±1.95 | 15.06 ±0.53 | 0.622 ±0.03 | 11.497 ±0.96 |
| Range | 16.30-236 | 897.9-2589 | 39.78-194 | 9.56-70.29 | 10.78-27.42 | 0.371 -1.203 | 0.651 -26.090 |
| *Critical levels | <50 | 1000-2000 | $20^{a}$ | 30 | $5\text{-}10^{b}$ | <0.10 | 10 |

Data (N = 6) were analyzed for Mean±SE (Standard Error)

Data presented in a column with different superscript ($^{a,b,c,d,e}$) differed significantly ($P<0.05$)

*Critical levels, [McDowell et al. 1984]; [a][McDowell 1985]; [a][McDowell et al. 1983]; [b][Marschner, 1986]

**Table 6.3:** Certain essential mineral concentration (ppm) in Lucerne (*Medicago sativa* L.) from cold desert high altitude region

| Study sites | Fe | Mg | Mn | Zn | B | Co | Cu |
|---|---|---|---|---|---|---|---|
| 1 | 370.43$^{bc}$ ±24 | 2743$^{ab}$ ±71.8 | 72.29$^{c}$ ±2.3 | 28.77$^{a}$ ±1.19 | 11.88$^{a}$ ±0.44 | 0.757$^{c}$ ±0.13 | 6.103$^{a}$ ±0.22 |
| 2 | 470.99$^{c}$ ±50.9 | 2565.4$^{ab}$ ±334 | 64.92$^{ab}$ ±3.3 | 63.54$^{c}$ ±8.52 | 19.70$^{abc}$ ±2.3 | 0.553$^{bc}$ ±0.04 | 15.496$^{abc}$ ±0.57 |
| 3 | 20.64$^{a}$ ±1.7 | 2489.8$^{ab}$ ±83.3 | 42.59$^{ab}$ ±1.6 | 44.46$^{b}$ ±1.29 | 14.22$^{ab}$ ±0.49 | 0.496$^{ab}$ ±0.04 | 19.645$^{abc}$ ±10.5 |
| 4 | 100.52$^{a}$ ±16.9 | 2764.4$^{ab}$ ±171 | 69.57$^{ab}$ ±12 | 104.95$^{e}$ ±5.1 | 14.05$^{ab}$ ±0.58 | 0.464$^{ab}$ ±0.05 | 23.39$^{abc}$ ±6.19 |
| 5 | 76.12$^{a}$ ±3.9 | 2368.8$^{ab}$ ±263 | 56.68$^{ab}$ ±8.4 | 38.94$^{ab}$ ±1.04 | 29.86$^{bcd}$ ±8.7 | 0.432$^{ab}$ ±0.04 | 11.706$^{ab}$ ±0.91 |
| 6 | 184.24$^{ab}$ ±69.5 | 2355.2$^{ab}$ ±82.2 | 71.36$^{c}$ ±0.5 | 30.11$^{a}$ ±3.62 | 34.16$^{cde}$ ±3.2 | 0.462$^{ab}$ ±0.04 | 22.938$^{abc}$ ±0.93 |
| 7 | 186.97$^{ab}$ ±33.1 | 2165.4$^{a}$ ±351 | 48.51$^{ab}$ ±1.6 | 60.80$^{c}$ ±2.73 | 46.29$^{de}$ ±3.49 | 0.323$^{a}$ ±0.06 | 21.668$^{abc}$ ±1.35 |
| 8 | 202.30$^{ab}$ ±7.3 | 2217$^{ab}$ ±51.2 | 39.84$^{a}$ ±8.5 | 28.08$^{a}$ ±2.73 | 48.58$^{e}$ ±5.12 | 0.525$^{ab}$ ±0.03 | 10.252$^{ab}$ ±2.65 |
| 9 | 159.01$^{ab}$ ±2.9 | 2086$^{a}$ ±51.54 | 49.18$^{ab}$ ±2.3 | 84.17$^{d}$ ±1.28 | 31.32$^{cd}$ ±0.77 | 0.322$^{a}$ ±0.02 | 8.189$^{ab}$ ±0.29 |
| Mean | 183.23 ±27.5 | 2598.78 ±94.3 | 61.71 ±3.4 | 51.09 ±3.42 | 29.93 ±2.30 | 0.497 ±0.02 | 17.452 ±1.72 |
| Range | 16.26-1342 | 1709-5748 | 21.40-161.3 | 21.56-119.2 | 10.76-76.3 | 0.217 –1.195 | 5.345 –61.710 |
| *Critical levels | <50 | 1000-2000 | 20$^{a}$ | 30 | 20-70$^{\mathbf{b}}$ | <0.10 | 10 |

Data (N = 6) were analyzed for Mean±SE (Standard Error).
Data presented in a column with different superscript ($^{a,b,c,d,e}$) differed significantly (P<0.05).
*Critical levels, [McDowell et al., 1984]; [a] [McDowell, 1985]; [a][McDowell et al., 1983]; [b][Marschner, 1986]

**Table 6.4** Certain essential mineral concentration (ppm) in native sheep (*Ovis aries* L.) from cold desert high altitude region

| Study sites | Fe | Mg | Mn | Zn | Co | Cu | B |
|---|---|---|---|---|---|---|---|
| 1 | $36.91^{d}$ ±6.4 | $31.59^{de}$± 1.30 | $8.01^{bc}$ ±0.7 | $2.47^{b}$ ±0.59 | $0.459^{d}$ ±0.05 | $7.126^{b}$ ±0.941 | $2.06^{ab}$ ±0.94 |
| 2 | $27.90^{cd}$ ±4.2 | $34.19^{e}$± 1.34 | $6.85^{b}$ ±0.1 | $3.51^{c}$ ±0.52 | $1.246^{f}$ ±0.05 | $8.999^{c}$ ±0.072 | $0.40^{a}$ ±0.01 |
| 3 | $12.12^{ab}$ ±1.1 | $25.97^{bc}$± 2.41 | $7.86^{bc}$ ±0.4 | $2.10^{ab}$ ±0.77 | $0.778^{e}$ ±0.16 | $5.821^{b}$ ±1.432 | $5.58^{bc}$ ±2.2 |
| 4 | $12.40^{ab}$ ±1.1 | $28.25^{cd}$± 1.15 | $8.21^{bc}$ ±0.4 | $1.24^{a}$ ±0.13 | $0.168^{bc}$ ±0.03 | $1.080^{a}$ ±0.096 | $3.19^{abc}$ ±0.7 |
| 5 | $17.85^{bc}$ ±2.2 | $29.65^{cd}$± 1.61 | $6.70^{b}$ ±0.7 | $1.21^{a}$ ±0.05 | $0.003^{a}$ ±0.02 | $1.246^{a}$ ±0.104 | $0.87^{a}$ ±0.46 |
| 6 | $15.85^{b}$ ±6.9 | $28.39^{cd}$± 1.35 | $9.07^{cd}$ ±1.1 | $1.08^{a}$ ±0.06 | $0.503^{e}$ ±0.06 | $1.161^{a}$ ±0.049 | $14.03^{e}$ ±3.3 |
| 7 | $3.43^{a}$ ±0.67 | $23.31^{b}$ ±1.46 | $9.96^{d}$ ±0.70 | $1.38^{a}$ ±0.16 | $0.015^{ab}$ ±0.02 | $0.998^{a}$ ±0.054 | $10.71^{de}$ ±0.9 |
| 8 | $1.62^{a}$ ±0.4 | $15.63^{a}$ ±1.47 | $5.00^{a}$ ±0.70 | $1.28^{a}$ ±0.05 | $0.244^{c}$ ±0.04 | $0.870^{a}$ ±0.080 | $11.08^{de}$ ±1.8 |
| 9 | $4.09^{a}$ ±2.5 | $14.82^{a}$ ±1.08 | $7.54^{bc}$ ±0.20 | $1.54^{ab}$ ±0.14 | $0.567^{d}$ ±0.06 | $0.760^{a}$ ±0.055 | $5.99^{bc}$ ±0.25 |
| Mean | 13.62 ±1.6 | 25.43 ±0.74 | 7.69 ±0.3 | 1.74 ±0.12 | 0.407 ±0.04 | 2.796 ±0.325 | 6.01 ±0.59 |
| Range | 0.1-87.5 | 7.0-40.7 | 0.3-15.8 | 0.7-8.3 | 0.100-1.519 | 0.456-10.520 | 0.1-38.7 |
| *Critical levels | <1.0 | <20 | <0.2 | <0.6 | NS | <0.65 | NS |

Data (N=10) were analyzed for Mean±SE (Standard Error).
Data presented in a column with different superscript ($^{a,b,c,d,e}$) differed significantly ($P<0.05$).
*Critical levels, [McDowell, 1987]

The present study revealed that, the levels of Fe, Mg, Mn, Co, Cu, Zn and B were observed to be ranged from 0.70-58.55, 8.29-35.30, 3.07-18.30, 0.089-1.142, 0.638-9.238, 0.09-2.65 and 0.53-24.73 ppm respectively in native goat, while the their mean concentrations were observed to be 11.54±2.50, 24.01±1.28, 6.84±0.55, 0.421±0.07, 3.328±0.62, 1.48±0.13 and 6.23±0.92 ppm respectively in native goat (Table 6.5).

**Table 6.5:** Certain essential mineral concentration (ppm) in native goat (*Capra hircus* L.) from cold desert high altitude region

| Study sites | Fe | Mg | Mn | Zn | Co | Cu | B |
|---|---|---|---|---|---|---|---|
| 1 | 32.08$^{b}$ ±6.74 | 30.81$^{c}$± 2.32 | 6.64$^{b}$ ±0.04 | 1.08$^{b}$ ±0.03 | 0.352$^{c}$ ±0.02 | 8.951$^{c}$ ±0.08 | 1.58$^{a}$ ±0.37 |
| 2 | 25.76$^{b}$ ±5.13 | 27.38$^{bc}$ ±2.13 | 6.78$^{b}$ ±0.14 | 1.18$^{b}$ ±0.10 | 0.323$^{c}$ ±0.02 | 8.768$^{c}$ ±0.14 | 0.68$^{a}$ ±0.06 |
| 3 | 1.19$^{a}$ ±0.03 | 29.40$^{c}$ ±0.46 | 9.84$^{c}$ ±0.31 | 1.84$^{c}$ ±0.19 | 0.231$^{b}$ ±0.08 | 0.989$^{ab}$ ±0.05 | 9.64$^{c}$ ±0.62 |
| 4 | 1.33$^{a}$ ±0.13 | 22.50$^{b}$ ±2.57 | 9.55$^{bc}$ ±2.68 | 2.42$^{d}$ ±0.07 | 0.131$^{a}$ ±0.01 | 1.162$^{b}$ ±0.05 | 15.34$^{d}$ ±2.79 |
| 5 | 2.47$^{a}$ ±0.20 | 13.47$^{a}$ ±1.31 | 3.16$^{a}$ ±0.04 | 2.02$^{c}$ ±0.07 | 0.159$^{b}$ ±0.01 | 0.803$^{a}$ ±0.05 | 5.16$^{b}$ ±0.43 |
| 6 | 11.80$^{a}$ ±4.92 | 26.35$^{bc}$ ±1.10 | 7.23$^{bc}$ ±0.03 | 0.25$^{a}$ ±0.13 | 1.005$^{d}$ ±0.03 | 1.229$^{b}$ ±0.11 | 5.72$^{b}$ ±0.91 |
| Mean | 11.54 ±2.50 | 24.01 ±1.28 | 6.84 ±0.55 | 1.48 ±0.13 | 0.421 ±0.07 | 3.328 ±0.62 | 6.23 ±0.92 |
| Range | 0.70-58.55 | 8.29-35.30 | 3.07-18.30 | 0.09-2.65 | 0.089-1.142 | 0.638-9.238 | 0.53-24.73 |
| *Critical levels | <1.0 | <20 | <0.2 | <0.6 | NS | <0.65 | NS |

Data (N=10) were analyzed for Mean±SE (Standard Error).
Data presented in a column with different superscript ($^{a,b,c,d}$) differed significantly (P<0.05); *Critical levels, [McDowell, 1987].

### 6.3.4 Correlation coefficient in soil-forage-animals

Pearson correlation coefficient ($r^2$) analysis disclosed that, Mg level in soil was significantly (P<0.01) positively ($r^2$=0.420**) correlated with their level in *Medicago sativa* L. and significantly (P<0.05) negatively ($r^2$=0.356*), although other mineral elements in agriculture soil were observed to be non significant (P<0.01; P<0.05) with their levels in native sheep and goat animals (Table 6.6).

**Table 6.6:** Correlation coefficient ($r^2$) between agriculture soil and forages from cold desert high altitude microclimate

| Essential mineral nutrients | Soil-Forages | Essential mineral nutrients | Soil-Forages |
|---|---|---|---|
| Magnesium (Mg) | | Zinc (Zn) | |
| Soil with *Medicago sativa* L. | 0.420** | Soil with *Medicago sativa* L. | -0.246 |
| Soil with *Triticum aestivum* L. *straw* | -0.356* | Soil with *Triticum aestivum* L. *straw* | 0.115 |
| Manganese (Mn) | | Iron (Fe) | |
| Soil with *Medicago sativa* L. | 0.066 | Soil with *Medicago sativa* L. | -0.007 |
| Soil with *Triticum aestivum* L. *straw* | -0.226 | Soil with *Triticum aestivum* L. *straw* | -0.252 |
| Boron (B) | | Cobalt (Co) | |
| Soil with *Medicago sativa* L. | -0.198 | Soil with *Medicago sativa* L. | 0.265 |
| Soil with *Triticum aestivum* L. *straw* | -0.027 | Soil with *Triticum aestivum* L. *straw* | -0.123 |
| Copper (Cu) | | | |
| Soil with *Medicago sativa* L. | 0.038 | | |
| Soil with *Triticum aestivum* L. *straw* | 0.047 | | |

*Correlation is significant at the P<0.05 level
**Correlation is significant at the P<0.01 level

The level of Zn in *Triticum aestivum* L. straw was significantly (P<0.05) negatively ($r^2$=0.368*) correlated with their level in native sheep, Mn content in *Triticum aestivum* L. straw was significantly (P<0.01) negatively ($r^2$=0.478**) correlated with their level in native goat and also the Fe and Co concentrations in *Medicago sativa* L. were found to be significantly (P<0.01) positively ($r^2$=0.394*; 0.394*) correlated their levels in serum samples of local goat (Table 6.7). The Fe content in soil was examined to be significantly (P<0.05) negatively ($r^2$=0.213*) correlated with their content in native sheep (Table 6.8). B was deficient in *Medicago sativa* L.

**Table 6.7:** Correlation coefficient (r) between forages and animals from cold desert high altitude microclimate

| Essential mineral nutrients | Plant-goat | Essential mineral nutrients | Plant-sheep |
|---|---|---|---|
| Zinc (Zn) | | Zinc (Zn) | |
| *Medicago sativa* L. *with native goat* | -0.016 | *Medicago sativa* L. *with native sheep* | 0.226 |
| *Triticum aestivum* L. *straw with native goat* | 0.313 | *Triticum aestivum* L. *straw with native sheep* | -0.368* |
| Magnesium (Mg) | | Magnesium (Mg) | |
| *Medicago sativa* L. with native goat | 0.094 | *Medicago sativa* L. with native sheep | 0.052 |
| *Triticum aestivum L.* straw with native goat | 0.214 | *Triticum aestivum* L. straw with native sheep | -0.129 |
| Boron(B) | | Boron (B) | |
| *Medicago sativa* L.*with native goat* | -0.106 | *Medicago sativa* L. *with native sheep* | 0.218 |
| *Triticum aestivum L. straw with native goat* | 0.008 | *Triticum aestivum* L. *straw with native sheep* | 0.011 |
| Manganese (Mn) | | Manganese (Mn) | |
| *Medicago sativa* L. *with Pashmina goat* | 0.186 | *Medicago sativa* L.*with native sheep* | -0.238 |
| *Triticum aestivum L. straw with native goat* | 0.478** | *Triticum aestivum L. straw with native sheep* | 0.114 |
| Iron (Fe) | | Iron (Fe) | |
| *Medicago sativa* L. *with native goat* | 0.394* | *Medicago sativa* L. *with native sheep* | -0.007 |
| *Triticum aestivum L. straw with native goat* | -0.019 | *Triticum aestivum* L. *straw with native sheep* | 0.082 |
| Cobalt (Co) | | Cobalt (Co) | -0.139 |
| *Medicago sativa* L. native goat | 0.503* | *Medicago sativa* L. native sheep | 0.063 |
| *Triticum aestivum* L. native goat | -0.047 | *Triticum aestivum* L. native sheep | |
| Copper (Cu) | | Copper (Cu) | |
| *Medicago sativa* L. native goat | 0.045 | *Medicago sativa* L. native sheep | -0.080 |
| *Triticum aestivum* L. native goat | 0.084 | *Triticum aestivum* L. native sheep | 0.241 |

*Correlation is significant at the P<0.05 level
**Correlation is significant at the P<0.01 level

**Table 6.8:** Correlation coefficient ($r^2$) between soil and animal sfrom cold desert high altitude microclimate

| Mineral nutrients | Soil-Native goat | Mineral nutrients | Soil-Native sheep |
|---|---|---|---|
| Fe | 0.276 | Fe | -0.213* |
| Mn | -0.272 | Mn | -0.097 |
| Mg | 0.015 | Mg | -0.038 |
| Zn | -0.333 | Zn | -0.154 |
| B | -0.192 | B | -0.529** |
| Co | -0.243 | Co | -0.146 |
| Cu | 0.104 | Cu | 0.304** |

*Correlation is significant at the P<0.05 level
**Correlation is significant at the P<0.01 level

## 6.4 Discussion

### 6.4.1 Levels of essential minerals in soil, forages and serum samples of sheep and goats

#### 6.4.1.1 Iron (Fe)

Our findings revealed that, total iron concentration in agriculture soil from cold desert high altitude environment, examined within the normal range of world soil and above the critical deficiency limit that is at <20.0 ppm [McDowell et al.,1984], similar findings have been reported by Ranjha et al. [1987] and Khan et al. [2006]. Fe deficiency in plants, humans and animals is a worldwide problem [Gibson, 2005]. In crop plants Fe deficiency occurs in various regions, on various soils types and in many Fe deficient crop species [Sillanpaa, 1982]. The critical deficiency level (CDL) for total iron in plant leaves ranges from 30-50 ppm [Bergmann, 1988], 70 ppm [Tanaka and Yoshida, 1970], CDL is much higher in fast growing tissues presumably in the range of 200 ppm for the total iron [Haussling et al., 1985]. Tanaka and Yoshida [1970] indicated 70 ppm Fe as deficiency limit, the sufficiency range of Fe in plant tissue is between 50 -250 ppm, generally when Fe content <50 ppm deficiency is likely to occur [Havlin et al., 2010]. Our finding of fodder plants disclosed that the Fe concentrations was ranges from 16.26-1768 ppm and the total mean concentration is estimated to 218.4 ppm on dry matter basis and our findings were in optimum level. Similar findings were also reported by Malik and Chughtai [1979] that higher iron contents in Lucerne, Berseem and wheat straw. It was further predicted that, Fe contents in plant vary with the species (leguminous grasses contain more Fe than cereal grasses), vegetative stage (decreases with age), soil type and environmental pollution [Sarwar and Hasan, 2001]. The level of Fe in serum samples of native sheep and goats above the critical limit suggested by McDowell [1987] and examined to be adequate for the goat and sheep. These results support the report of McDowell et al. [1984] which indicated that Fe deficiency is rare in grazing animals due to usually adequate contents in soils and fodders. The critical level of Fe for ewes and rams are at 182 mg/dl and 152 mg/dl respectively [Underwood and Morgan, 1963]. High serum might have been caused by the comparatively high Fe content of the forage grazed and probably due to high Fe absorption by the sheep [Haenlein, 1980]. The higher level of serum Fe in studied animals may be due the higher level of Fe in soil and fodders growing in this region.

#### 6.4.1.2 Magnesium (Mg)

The present findings revealed that, Mg concentration in agriculture soil were observed to be above the critical deficiency limit (<120 ppm) suggested by McDowell et al. [1984] and further these concentrations were found with typical range of world soils. So the Mg level present in cold arid agriculture soil is considered to be adequate for the crop production. Mg concentrations in fodders depends largely on the plant species and the seasonal and climatic conditions during plant growth, but soil origin seems to has little importance [Jumba et al., 1995], grasses in temperate and tropical pastures contain on average 1.8 and 3.6 ppm of Mg on DM basis, respectively and legumes 2.6-2.8 ppm DM [Minson, 1990]. Our present findings in lucerne and wheat straw were examined above the critical level (1000-2000 ppm) in lucerne while in the wheat straw it was observed within the range of critical level for Mg suggested by McDowell et al. [1983], so it indicates that cereals at this region have low Mg absorption potential than the legumes (lucerne) at this region unlike their adequate levels in soils where it is grown. The minimum need of Mg for growth of sheep generally met by feed or fodders containing 700 ppm of Mg on dry matter basis and critical Mg level in fodders for adult sheep is 1000 ppm given by McDowell et al. [1993]. The total mean level of Mg in serum samples of native sheep and goats were observed above the critical level (<20 ppm) predicted by McDowell [1987], but in some study sites it was observed below the critical level (<20 ppm) both in sheep and goats at this region.

### 6.4.1.3 Manganese (Mn)

The earlier studies predicted that, the status of total Mn in Indian soils is adequate varying from 37-11500 ppm and available status 0.6 to 164 ppm [Alloway, 1995]. Although our present findings showed Mn levels in agriculture soil within the adequate range of soils and much above the available status [Alloway, 1995]. In addition to this, Mn content was observed above the critical deficiency limit [McDowell et al., 1984] in agriculture soil at this region. The manganese concentration in plants typically rages from 20-500 ppm while Mn deficient plants contain <15-20 ppm on dry matter basis; Mn deficiency resembles Mg deficiency to some extent, the critical deficiency limits for Mn ranges from 10-15 ppm in mature leaves of plants, while the critical toxicity limits have a much wider range 650-5000 ppm that is reported in rice [Hannam and Okhi, 1988]. Our present findings disclosed that, Mn in studied fodder crop plants were found in adequate quantity for the growth and development of crop plants and examined above their critical deficiency limit (<20 ppm) proposed by McDowell et al. [1983].The level of Mn in serum samples of sheep and goats from cold desert high altitude region were reported above critical level (0.2 ppm) proposed by McDowell [1987] for the adult sheep and this level was further proposed by Underwood [1999] and McDowell et al. [1993] which is 20-40 mg/dl in serum samples of growing and adult sheep. Therefore the result indicates that Mn concentrations in animals reared at this region have adequate amount.

### 6.4.1.4 Zinc (Zn)

The total and available form of Zn content in soils in India ranged from 7-2960 and 0.1-24.6 ppm respectively with an average deficiency of 12 to 87% [Singh, 2000]. Although, the Zn can be supply both from ophiolite and sedimentary rocks of the area, but the level is much lower than the world average (64 ppm), so poor availability in soils is due to long time agricultural practices. The total average concentration of zinc in soil was reported to 86.668±2.85 ppm DM while the White [1993] and Havlin et al. [2010] reported that, Zn concentrations in soils ranges from 10-300 ppm DM and total mean concentration is 50 ppm [Vinogradov, 1959] but its concentrations varied according to soil class, our results were above the critical level [Jackson, 1973]. It is assumed that, cold arid soils have sound amount of total zinc concentration that indicates geological system and rock materials is filled with zinc forming minerals in this region. As it was reported that soils formed from the basic rocks such as basalt is rich in Zn concentrations. In India some Indian soils, Zn was estimated to 47 ppm was in Entisols, 60 ppm in Inceptisols, 61 ppm in Aridisols, 63 ppm in Vertisols, 44 in Alfisols and 72 in Oxisols, 43 in Ultisols, 30 Molisols soils.

Zinc is an essential micronutrient, required for the healthy growth of the plants. Zinc is either bound to organic acids during long distance transport in the xylem or may move as free divalent cations. The general critical deficiency level (CDL) of Zn in plant tissue is <20 ppm on dry matter basis however Zn CDL differ from crop to crop and from soil to soil [Prasad, 2007] The critical toxicity level (CTL) in plants may vary from 150-200 ppm [Prasad, 2007] while Gupta and Gupta [1998] reported 95-135 ppm in bush beans (*Phaseolus vulgaris* L.). The low availability of Zn in alkaline calcareous soils is one of the widest ranging chlorotic stresses in the world agriculture especially in cereals in Australia, Turkey, India, Pakistan and China [Marschner, 1995; Singh et al., 2005]. The Zn concentration in plants varied from 25-150 ppm and deficiency is usually associated with concentrations of less than 10-20 ppm, depending on the crops and the toxicities will occur when the leaf concentrations exceeds 400 ppm [Havlin et al., 2010]. Our present study revealed that Zn concentration in fodder crops grown in this region particularly in wheat straw and Lucerne were observed to be above the critical level (<30 ppm DM) and available in optimum content for the growth and their performance. Minson [1990] had reported high content of Zn in pastures on worldwide basis that is 25-50 ppm DM. This adequate level of Zn in fodders may be due to the higher level of Zn in soil. The level of Zn in serum samples of sheep and goats were reported above the critical level (0.6 ppm) and found within the normal range (15-50 ppm) suggested as adequate for adult sheep [Renner, 2001]). Underwood [1981] reported that Zn deficiency is unlikely to occur in sheep.

#### 6.4.1.5 Boron (B)

Deficiency of B occurs on a wider range of soils, crops and climatic conditions the deficiency of any other micronutrients [Reisenauer et al., 1973]. B is one of two non metal micronutrients, it occurs in low concentrations in the earth’s crust and in most igneous rocks (<10 ppm) and in sedimentary rocks. The total B concentration in soils varied between 2- 200 ppm and frequently ranges from 7-80 ppm [Havlin et al., 2010]. Our findings about the B concentration in agriculture soil varied from 34.98-126.1 ppm and average concentration was 80.133±3.51 ppm (Table 6.1) it was in normal range. Boron leaches down the soil profile and therefore soils of humid region such as sandy podzols, alluvial soils and organic soils have low amounts of plant available B. Sedimentary rocks generally contain higher levels of B than the igneous rocks. Some sedimentary rocks of marine origin can have 500 ppm or more concentration in soil which is related to the concentrations in parent materials and the degree of weathering. Low B content can be expected in soils derived from igneous soils, fresh water sedimentary deposits and in coarse textured soils low in organic matter. B content in soils is generally higher near the soils surface where organic matter concentration is higher. The critical level of B in soils is <0.5 ppm suggested by McDowell et al. [1983], although our results were examined above the critical limit in the present study. Higher level of B in agriculture soil may be due o the soil parent materials obtained from the sedimentary rocks which is expected to have high level of B forming mineral (shale, upto 100 ppm). The plant species differ in their requirements; the critical deficiency limit is 5-10 ppm DM in monocots, 20-70 ppm DM in dicots [Marschner, 1986; Gupta, 1993a]. Boron is considered toxic when its level exceeds 100 ppm in plant tissues on dry matter basis. Our present findings revealed that, boron concentrations in fodders were reported above the critical level in *Medicago sativa* L and *Triticum aestivum* L. at this region. The level of B in serum samples of sheep and goats were reported to be examined from 0.1-38.7 ppm (w/v) in native sheep (*Ovis aries* L.) and in native goat (*Capra hircus* L.) from 0.53- 24.73 ppm (w/v) these results are in the normal range for sheep and goats. The essentiality of B was still not established but some time it is considered as beneficial to the animals.

#### 6.4.1.6 Cobalt (Co)

In continuum of soil-plant-animals, plant acts as accumulator of Co and its conversion in vitamin $B_{12}$ in ruminants, ruminants require about 0.1ppm. Co deficiency is associated with ground water podzols and gley (low humic and poorly drained soil), soils of the Atlantic coastal plane, sandy soils and wet climate [Kubota et al., 1963]. Co deprivation arises on well drained soils of diverse geological origin, including coarse volcanic pumice soils of New Zealand [Suttle, 1988], leached podzolized sands of jutland, sandy loams of Goatland in Sweden [Schwan et al., 1987], soils derived from granites and limestone gravels, as well as on the calcareous, wind-blown shell sands. Cobalt status in Indian soils ranges between 20-1000 ppm with an available status of 0.5-10 ppm. Its deficiency occurred on soils containing 4.4-47 ppm in marginal to deficient areas soils contain 3-4 ppm and in deficient areas 1-2 ppm soil. The level of Co in agriculture soil from the present study were examined much higher than their critical level in soils (<0.1 ppm) suggested by McDowell et al. [1983]. Cobalt concentrations in pastures and fodders vary widely between plant species and with soil conditions [Minson, 1990]. In early Scottish studies, cobalt concentrations in mixed pastures ranged from 0.02 to 0.22 ppm on dry matter basis and legumes were richer in cobalt than grasses grown in the same conditions, red clover and rye grass containing 0.35 and 0.18 ppm on dry matter basis respectively [Underwood and Suttle, 1999). High level of Mn depress the availability of soil Co to plants and the risk of Co deprivation may be predicted from equations that relate soil available cobalt to soil Mn [Suttle et al., 2003; Li et al., 2004]. The content of Co in the present study were noted above the critical limit in wheat straw and *Medicago sativa* L. and this higher level of Co may be due to their higher level in soil at this cold arid region. It was reported that, Co responsiveness is poorly correlated with pasture cobalt in sheep [Gruner et al., 2004a], however it is clear that grazing cattle have lower needs than sheep and cattle may not benefit from Co supplementation on pasture containing 0.06 ppm DM that cause clinical deprivation in lambs [Clark et al., 1986]. Ruminants required about 0.1 ppm on dry matter basis, while our results reported that, serum Co content noted to be within the normal range (1-3µg/L) for the sheep and goats so there is no deficiency of cobalt in sheep and goats reared at this region. Cobalt has received most attention as a nutrient supplement for ruminants, because it is a proven essential trace element for ruminants. Co deficiency symptoms in ruminants include lack of growth and poor reproductive ability [Underwood, 1977] Co deficiency disease in sheep and cattle is known as bush sickness in New Zealand, wasting disease in west Australia and pining in Great Britain [Underwood, 1981]. Toxicity of Co will occur in ruminants above the 10 ppm, but the level of Co observed in our present study is again too low in serum samples of sheep and goats, thus no health risk to the livestock. Cobalt concentration in various soils and sediments from our study was observed rather high but seemed lower transfer rate from the soil to forage in this region.

**6.4.1.7 Copper (Cu)**

Our findings noted that, copper level in agriculture soil was observed to be much higher than their critical limit is soils [McDowell et al., 1984], this higher level of Cu in the present soil may be due to soil developed from fine grained sedimentary rocks (shale and clays) or the basic igneous rocks. Cu is found in nature in form of sulfates, sulfides, sulfosalts, carbonates and chalcopyrite is most abundant Cu mineral. Soils derived from coarse grained materials (sands and sandstone) or from acid igneous rocks contain lower concentrations of Cu. The average concentrations of total Cu in world soils has been reported around 30 ppm (range 2-250 ppm). Agricultural soils normally ranges from 1-50 ppm of total Cu, and further total Copper content and available form of soil is ranged from 1.8-960 ppm and 0.1 to 32 ppm respectively. Severely weathered, leached and acid soils have relative low levels of compared to other soils. Copper is generally not a severe nutritional deficiency problem in Indian soils, only 3-4% of Indian soils are found deficient in copper. The level of Cu in fodders from cold arid region noted to be within the normal range for the plants and found above the critical limit (<10 ppm DM) for the crop plants suggested by McDowell et al. [1983]. In some studied site Cu was observed above toxic limit (>20 ppm DM), that is the point that must be taken into the consideration. The copper concentrations can range from 4.5 to 21.1 ppm DM among grass species grown on the same soil [Underwood and Suttle, 1999]. Cu is required in small concentrations (5-20 ppm) in plant tissues for normal growth, while tissue concentrations of <4 ppm are generally considered deficient, >20 ppm can be toxic to plants. The copper content of pastures and fodders varies with the species, stain and maturity of the plant, with certain soil conditions [McFarlane et al., 1990]. Temperate grasses tend to contain less copper than legumes grown in the same conditions (4.7 versus 7.8 ppm DM respectively) but under tropical conditions the situation is reversed (7.8 versus 3.9 ppm respectively) [Minson, 1990]. Copper deficiencies are likely to occur on peat and muck soils, alkaline and calcareous soils, poorly drained mineral soils, deep sandy soils low in native Cu and mineral soils high in organic matters. The concentration of Cu in serum samples of sheep and goats were reported above their critical deficiency limit (<0.65 ppm) suggested by McDowell [1987] and noted to be within the normal range for the growth of animals at this cold arid environment. The critical level of Cu in serum of sheep <0.5mg/100 ml, the Cu deficiency is widely distributed throughout the world and it is likely to occur when dietary Cu content in the pasture is lower than requirement of sheep at 7.0 mg/kg DM [NRC, 1985]. The low copper content of forage is indicative of likely deficiency and may be implicated for low serum Cu concentrations reflects the dietary status, however the normal range is high [Underwood, 1981]. It was reported that sheep fed with commercial concentrate containing Cu showed the sign of chronic Cu poisoning [Mollerka and Ribeiri, 2006] and the mean concentration was reported to

11.37 ppm and Cu levels in the liver and kidney were 1641 and 305 ppm respectively. Further Robinson [1994] reported copper content in goat kidney from 12.43 to 14.5 ppm which is toxic level.

**6.4.2 Correlation coefficient in soil-forage-animals**

The correlation analysis revealed that Mg level in soil examined to be significantly positively correlated with their level in *Medicago sativa* L. while it significantly negatively correlated with wheat straw; Mg level in fodders is positively correlated with their level on animals but were non-significant and from soil to animals have contradictory results. So it indicates that Mg absorption from soil largely depends upon plant type particularly at this region, animals have good Mg utilization potential from the plant resources but from soil to animals, it seemed to largely depend upon animal types. Bhat et al. [2011] in your study at Kashmir Valley predicted mostly the similar results, as Mg level in forages were negatively correlated with dairy cattle and positively correlation between soil and forages and soil with animals but were non-significant. In case of Mn levels in agriculture soil was positively with Lucerne and negatively correlated with wheat straw but were non-significant, levels in wheat straw significantly positively correlated with their level in native goat but in sheep it was non-significant, but soil with animals was negatively correlated and found non-significant. It indicates that Mn movement from plant to animal is quite good but proportion is seemed to be depends on soil quality and quantity, plant types and the animal species, but from soil to animals are seemed to be largely affected at this region, that may be due to the climatic conditions. The similar results were predicted by Tiwari et al. [2009] in their study at Haridwar, as positive non-significant correlation between soil and plants, soil and animals and plant to animals. Boron was negatively correlated between soil and plants, positively correlated with plant and animals except in native goat (non-significant) and from soil to animals, it was negatively correlated but at both, significant and non-significant level. The results showed that B largely influenced from soil to plants and soil to animals at this region it may be due to the low levels of available B in soils, but utilization of B from fodders to animals examined to be quite good. Regarding to the level of Fe, it was negatively correlated between soil and plants, but significantly positively correlated between lucerne and native goat, between soil and animals it was positive with goat and negative with sheep. It shows that, Fe availability in soil for the plants is largely affected by the nature of soil [alkaline (pH>7.5) and calcareous], while transfer rate from plant to animals seems to be quite good, therefore total Fe transfer from soil to animals is also affected. It was reported that, higher level of serum Fe might be due to comparatively higher Fe content of forages and higher absorption potential of sheep. Bhat et al. [2011] predicted in your study at Kashmir Valley as Fe was non-significantly positively correlated in soil-plant, plant-animals and soil-animals and further Yadav and Kirwar, [2005] in your study reported, Fe content in soil is positively correlated with Fe content in Berseem. In present study Zn was non-significantly positively and negatively correlated with wheat straw and lucerne respectively, between plant-animals, Fe significantly negatively correlated in wheat straw with sheep and in native goat it was positively correlated with wheat straw and in soil-animals it was observed negatively correlated (non significant). It was reported that Zn level in soil does not affect their level in fodders [Yadav and Kirwar, 2005] and also higher Mn and Fe in soil is adversely affected the Zn level of feed stuffs grown on the same soil. Zn level in soils did not affect its concentration if feed stuffs [Khalili et al., 1993]. Correlation analysis reports about Co which was found positively correlated between soil-plant (Lucerne), plant-animals (Lucerne) but negatively correlated in (soil-animal) systems so there is no complete interrelationship was generated at this region but raised some hopes of possibilities. The level of Cu in soil was positively correlated with their level in forages, from plant to animals and soil to animals, present findings about Cu revealed that, complete interrelationship approach was proved in soil-plant-animals system at this region.

## 6.5 Conclusion

The level of essential minerals in agriculture soil, fodders (lucerne & whet straw) and sheep and goats were observed with in the normal range. Most of the essential mineral nutrients in the blood serum of local sheep and goats were investigated and results were largely differed among the sampling locations. Correlation analysis revealed that some essential mineral elements are positively and some negatively correlated in soil with plant, plant with animals and soil with animals it shows that the availability and the dynamics of mineral elements in agriculture soil is highly affected by the existing harsh climatic conditions at this region. It is assumed that complexity of studied agriculture soil is directly affecting essential minerals transfer to the plant and animals. Fodders in our study have disclosed varied level of mineral nutrients accumulation and manifestations according to the fodder types thus this indicates, the fodders grown under this microclimate have their own potential to tackle these mineral availability and accumulation problems. Therefore care must be taken during mineral mixture formulation or any feed supplement at this region for the small and large animals because fodders from this region have different level of essential minerals with different responses to the each type of mineral element.

# CHAPTER VII

# To know certain heavy metals presence in agricultural soils of cold arid high-altitude region

**Abstract**

The present study was conducted to investigate the heavy metals status and their distribution in soils and sediments at cold desert high altitude region. The concentration and distribution of trace elements in soils is closely related to the nature of the parent rocks and minerals from which the soil is derived. Because soils acts as sink for the heavy metals. Presently the soil pollution is an important environmental issue that they are dangerous, due to their toxicity and persistence in the environment, metals can be transferred from soil to other ecosystem components, such as underground water, river and crops and then to animals that results risk to human health. Therefore the present study was done in Leh-Ladakh: small Tibet to know the heavy metals distribution in various soil ecosystems. For the study, grazing land, road side soil, agriculture soil and Indus river sediment were selected; soil samples were analyzed for Ni, Cr, As, Cd and Pb. Study revealed the total mean concentrations of As, Cr and Ni were observed to be 8.824±1.42, 99.273±7.18 and 75.533±6.72 mg/kg respectively in agricultural soil while they ranged from 1.88-27.03, 23.37-512.3 and 10.12-410.9 mg/kg respectively in agriculture soil. Apart from this the Ni content was significantly ($P<0.05$) higher found at site 10 (206.464±31.24 mg/kg), Cr at site 10 (169.952h±16.78 mg/kg) and As at site 3 (12.065d±4.72 mg/kg). Cd and Pb were not detected in any study site while the As was only found in some study sites 2, 3, 4, 5 of agriculture soil. Lead and cadmium were not detected in agriculture soil. Ni and Cr were found above the threshold limit in agriculture soil whereas other metals were below the threshold limit. The present study reported that the heavy metals are widely distributed in agriculture soil at cold arid high altitude and it indicates that the geological system, rocks and the parent material of this microclimate have heavy metals forming minerals.

**Key Words:** River sediment, soil ecosystems, cold desert, high altitude, microclimate, heavy metals

## 7.1 Introduction

Heavy metals are natural constituents of the earth crust. A number of these elements are biologically essential at trace levels present in natural water, air, dusts, soils and sediments and play an important role in plant, animal and human life. The natural concentrations of heavy metals in soils are a result of weathering that releases these metals from their host minerals during soil formation [Kabata-Pendias, 1993]. A close relationship between the metal content of the parent material and soils has been observed in a number of studies [Singh and Steinnes, 1994]. The mobility, solubility and bioaccumulation depend on the properties of the metals as well as the quality of soil, pH and other factors. Certain metals (Cr, Pb, Cd, Ni, As and others) are contributed through the weathering of igneous and sedimentary rocks in the soils. Apart from this, the river sediments are essential and integral parts of river ecosystem, provide the substrate for the living organisms and through interaction with overlaying waters such as nutrients cycling playing important roles in aquatic ecosystems (Tiedemann et al., 1988).

Soil surface deposits resulting from geological processes are the parent material from which soil develops. The physical, chemical and mineralogical characteristics of soil are a result of weathering of soil parent material over time. Weathering during soil formation results in physical disintegration and chemical decomposition of minerals and the release of metals from the parent material to the soil and to the solution in soil water and ground water. A close relationship between the metals content of parent material and soils that develop during weathering has been observed in a number of studies [Singh & Steinnes, 1994]. The physical and chemical properties of the soils are determined by the mineralogical and chemical composition of the igneous, carbonate and shale bedrock, the three rock types most likely to have been incorporated into the surface deposits. These rock materials weather over time to become the parent material for soil and ultimately determine the trace metals composition of the soil.

Sediment analysis can be used favorably to estimate point sources of pollutants that are being discharged into surface water whether through the ground water leakage, infiltration of runoff of irrigation water from soil surface, rain water, industrial waste discharge or through contact of river water with heavy metal forming minerals in geography or in rocks. The contaminants are not necessarily permanently fixed by sediments but they also may be recycled through biological and chemical agents within both the sedimentary compartment and the water column. Soils are critical environment where rock, air and water interface, consequently they are subjected to a number of pollutants due to different anthropogenic activities like industrial, agricultural, transport etc. [Facchinelli et al., 2001; Jonathan et al., 2004]. The chemical composition of soil, particularly its metal content is environmentally important, because toxic metals concentration can reduce soil fertility, can increase input to food chain, which leads to accumulation of toxic metals in food stuffs and ultimately can endanger human health. Because of its environmental significance, studies to determine risk caused by metal levels in soil on human health and forest ecosystem have attracted attention in recent years [Arantzazu et al., 2000; Krzysztof Loska et al., 2004].

All setbacks along major highways are used by farmers for vegetable cultivation. Emissions from the heavy traffic on these roads contain lead, cadmium, zinc and nickel, which are present in fuel as anti-knock agents. This has also led to contamination of air and soils on which these vegetables are planted [Ikeda et al., 2000]. Excessive accumulations of heavy metals in agricultural land through traffic emission may results in soil contamination and elevated heavy metal uptake by crops and thus affect food quality and safety [Ho and Tai, 1988; Garcia and Millan, 1998]. Food chain contamination is one of the important pathways for the entry of these toxic pollutants in to the human body [Ferner, 2001; Ma et al., 2001]. Plants can absorb heavy metals from soil as well as from air. The accumulation of heavy metals as well as metals predominantly toxic to plants in the soil can be a consequence of the natural lithogenic and pedogenic processes [Woolhouse, 1983] as well as anthropogenic factors which result in environmental pollution [Piperski and Radisic, 2003]. A very important source of heavy metals and other pollutants of soil and plants is passenger traffic [Memon et al., 2001; Stankovic et al., 2008a]. There is no specific study in this region on the various soil systems that can reveal the heavy metals status and their distribution, by keeping this point in mind the present study was designed with objectives to assess the level of heavy metals and their distribution throughout the soil systems from cold arid region microclimate.

## 7.2 Material and methods

### 7.2.1 Location and study conditions

The study was conducted in Leh-Ladakh, is cold desert high altitude, called as semi arctic region, known by its harsh climatic and terrestrial conditions, viz, subzero temperature, lower moisture content, low oxygen pressure, higher air speed, very diverse rock establishment and geological system and so many others. The investigated region is lies in Tibetan plateau and is some time called as small Tibet for their cultural, social and environments similarities with Tibet. Leh district is situated between $32^0$ to $36^0$N latitude and $75^0$ to $80^0$E longitude and at an altitude ranging from 2900 to 5900 m. amsl. The study area lies between $33^0$59’362 to $34^0$17’722 N latitude and $077^0$12’023 to $077^0$45’669 E longitudes and with at an elevation ranging from 10526 ±32.30 to 13063 ±20.20 ft. amsl.

### 7.2.2 Soil sampling and processing

Eleven study sites are selected for sampling from agriculture soil; six soil samples were collected randomly from each sampling site. For each sampling site ten sampling points were selected, samples were collected up to 20 cm soil depth. Root part and other plant residues were removed from the soil. All soil samples were air dried at room temperature, sieved with <2.0 mm test sieve and further it was grinded in stainless steel pestle and mortar and sieved with 200 µm of test sieve that is ready for sample preparation (digestion).

### 7.2.3 Sample preparation and analysis

All the soil samples were digested on dry matter basis, soil samples were digested by using metal grade HF (hydrofluoric acid), nitric acid and hydrochloric acid, samples were digested on 42 blocks Automated Hot Bock digestion system (Questron Technologies Inc., Canada). These all samples were analyzed for the estimation of heavy metals. Heavy metals were estimated in soil samples by Inductively Coupled Plasma-Optical Emission Spectroscopy (Optima 7000 DV, Perkin Elmer, United State of America), their detection limits were diven in Table 7.1.

### 7.2.4 Statistical analysis

The data generated through the study were analyzed for mean and standard error (SE) the significance level ($P<0.05$) was generated among the different studied sites of agriculture soil by one way ANOVA for Duncan multiple range test using the SPSS statistical software, 11.5 version, SPSS Inc., USA (SPSS, 1999).

## <u>7.3 Result</u>

Study revealed the total mean concentrations of As, Cr and Ni were observed to be 8.824±1.42, 99.273±7.18 and 75.533±6.72 mg/kg respectively in agricultural soil while they ranged from 1.88-27.03, 23.37-512.3 and 10.12-410.9 mg/kg respectively in agriculture soil (Table 7.1). Apart from this the Ni content was significantly ($P<0.05$) higher found at site 10 (206.464±31.24 mg/kg), Cr at site 10 (169.952±16.78 mg/kg) and As at site 3 (12.065d±4.72 ppm). Cd and Pb were not detected in any study site while the As was only found in some study sites 2, 3, 4, 5 of agriculture soil in this region (Table 7.2).

**Table 7.1:** Detection limit of ICP-OES (Optima 7000DV, Perkin Elmer) and threshold limit of studied heavy metals in soil

| Heavy metals | Detection Limit (µg/l) | Threshold limit* (ppm) |
|---|---|---|
| Arsenic | 5.7 | 12[b] |
| Cadmium | 0.1 | 1[a] |
| Chromium | 0.3 | 64[b] |
| Cobalt | 0.4 | - |
| Lead | 1.5 | 70[b] |
| Nickel | 0.5 | 50[b] |

*Threshold limit: [a] [Eduardo et al., 2010 & Alvarenga, 2006]; [b] [CCME, 1999]

**Table 7.2:** Heavy metals concentration (mg/kg) in agriculture soil from cold desert high altitude region

| Study sites | As | Cd | Pb | Cr | Ni |
|---|---|---|---|---|---|
| 1. | ND | ND | ND | 164.96[h]±8.17 | 151.056[h]±21.92 |
| 2. | 8.8578[c]±0.23 | ND | ND | 107.55[efg]±2.57 | 81.876[def]±2.05 |
| 3. | 12.065[d]±4.72 | ND | ND | 157.28[h]±12.15 | 120.260[gh]±8.45 |
| 4. | 4.405[b]±0.74 | ND | ND | 106.388[efg]±18.09 | 65.458[cde]±1.94 |
| 5. | 11.26[d]±2.95 | ND | ND | 138.18[gh]±2.59 | 115.104[fg]±2.51 |
| 6. | ND | ND | ND | 93.74[def]±1.35 | 72.210[de]±1.64 |
| 7. | ND | ND | ND | 90.658[def]±5.81 | 65.284[cde]±5.49 |
| 8. | ND | ND | ND | 71.428[bcde]±3.62 | 49.368[abcd]±1.99 |
| 9. | ND | ND | ND | 62.894[abcd]±12.26 | 55.284[bcd]±18.2 |
| 10. | ND | ND | ND | 169.952[h]±16.78 | 206.464[i]±31.24 |
| 11. | ND | ND | ND | 95.352[def]±8.01 | 76.774[de]±8.32 |
| Mean | 8.824±1.42 | | | 99.273±7.18 | 75.533±6.72 |
| Range | 1.88-27.03 | | | 23.37-512.3 | 10.12-410.9 |

Value (Mean±SE, N=6) bearing different superscripts differ significantly ($P<0.05$) between the row.

## 7.3 Discussion

### 7.3.1 Nickel (Ni)

Nickel minerals viz. Millerite, pentlandite, niccolite will release as $Ni^{2+}$ upon weathering into soil which is more stable in soils. Nickel is extremely high in ultramafic rocks (1400-2000 ppm) and lowers in mafic rocks (130-160 ppm) (Table 7.3) and in sedimentary rocks it is highest in organic rich shales (40-90 ppm) [Kabata Pendias & Pendias, 1999]. The most imperative Ni mineral is pentlandite and nickel occurs as a constituent of pyrrhotite and ferromagnesian minerals [Garrett, 1998]. The Ni concentration in world soils ranges from 1.0 to 450 ppm while the total mean content observed to be 40 ppm [McGrath and Smith, 1990] and further typical range in world soils is reported to 0.1-1523 ppm [Wild, 1988]. Mean nickel content in soils of the world varies between 8-33 ppm and 10-92 ppm for the light and heavy soils respectively [Kabata Pendias & Pendias, 1999]. Generally content of 100 ppm is recognized as an acceptable level in farmland soil [Kabata Pendias & Pendias, 1999]. The present investigation predicted that nickel concentration studied area differed widely and found above the world soil's average content in our studied soils and sediments samples [McGrath and Smith, 1990]. Study also reported the health risk through the higher level of Ni that is estimated above threshold limit [CCME, 1999] can cause difficulty to terrestrial ecosystem and the living beings of present study area. Bioavailability of Ni decreases in alkaline pH. Furthermore, presence of Fe-Mn oxides and high organic matter also lower its availability to plants [NRCC, 1981]. Despite the toxicity, Ni is easily translocated within plants and commonly accumulates in high quantities in leaves, exhibiting chlorosis [Kabata-Pendias & Pendias, 1992]. Ni content in soils mainly depends on its concentration in bedrock [Terelakh et al., 2000], soil clay content, sewage sludge application and nickel deposition from polluted atmosphere. This is lower than Ni content (10 ppm) recognized as nickel limit concentration in light soils [Kabata-Pendias et al., 1995].

**7.3.2 Chromium (Cr)**

There are high amounts of chromium in ultramafic rocks (1600-3400 ppm) and lower amount in felsic rocks (4-25 ppm) and sedimentary rocks (5-120 ppm) [Kabata-Pendias & Pendias, 1992] and the amount of Cr in soils ranges from range from 1.4-1100 ppm (Table 7.3), depending on the soil type with an average worldwide level of 54 ppm Cr for surface soils [Kabata-Pendias & Pendias, 1992] and further critical level in soils varies from 0.9 to 1500 ppm [Wild, 1988]. The chromium forming minerals are chromite ($FeCr_2O_7$), spinel [Kabata-Pendias & Pendias, 1992], ferromagnesian [Garrett, 1998] and naturally occurring forms in soil are chromite ($Cr^{3+}$) and chromate ($CrO_4^{2-}$), $Cr^{3+}$ is the more stable form in the soil [Kabata-Pendias & Pendias, 1992]. Our findings showed that Cr concentrations in different soils and sediments distributed widely and found within the normal range of soils [Wild, 1988] and also observed above the world average (54 ppm), most of the samples were determined Cr levels above the threshold limit [Eduardo et al., 2010; Alvarenga, 2006]. So there is a risk to living beings and to the ecosystem of cold arid region through the Cr contamination of soils. Chromate is resistant to weathering but oxidize to chromate ($Cr^{6+}$), $Cr^{3+}$ is less mobile under acid soil conditions but mostly precipitated at pH 5.5, whereas presence of organic matter promotes reduction of $Cr^{6+}$ to $Cr^{3+}$ that results low Cr availability to the plants [Kabata-Pendias & Pendias, 1992]. Alkaline nature (pH >7.5) of cold arid soils is particularly affecting the Cr dynamics such as their retention and mobility in the soils. It was reported that the sandy and organic soils have low Cr [Kabata-Pendias & Pendias, 1992] although sandy soils have more availability of $Cr^{3+}$ due to lower cation exchange capacity [NRCC, 1976].

**7.3.3 Cadmium (Cd)**

Cd is very mobile in the soil environment, especially in light and acid soils; due to this fact even a moderate concentration of cadmium in the soil can considerably influence its uptake by plants. Natural Cd content in soils depends on the soils bedrock, granulometric composition, age of soils, intensity of soil parent rocks weathering and their geological origin. Concentration of cadmium in soils in different parts of the world varies between 0.2-1.05 ppm, but generally does not exceed 0.5% [Kabata Pendias & Pendias, 1999] and in earth's crust level is 0.2 ppm and ranges from 0.1 to 0.5 ppm, Garrett [1998] (Table 7.3). The highest content occurs in landscapes in which the soils are derived directly from shale bedrock or in which a large content weathered shale particles comprise the soil parent material. In a report Cd in soils of Poland contain an average of 0.21ppm and with a variation range of 0.01-49.73 ppm [Kabata Pendias & Pendias, 1999]. Cadmium can alter the uptake of minerals by plants through its effect on the availability of minerals from the soil or through a reduction in the population of soil microbes [Morenno et al., 1999], but accumulation in sedimentary rocks, marine phosphate and phosphorites may be 500 ppm [WHO, 1992]. Due to weathering and erosion of rocks, it is anticipated that 15000 metric tons of Cd is transported to oceans through rivers [WHO, 1992; OECD, 1994]. Cadmium is found primarily in sulphide minerals such as sphalerite and pyrite (Garrett 1998), upon the weathering, these minerals will release $Cd^{2+}$ into solution and this form is taken up by plants but due to their low content in soil solution $Cd^{2+}$ will form complexes ions and organic chelates in soil, In alkaline soil Cd mobility is controlled by precipitation of cadmium compounds so this nature of soil can play major role in Cd dynamics in our studied region due to its alkaline nature ($CdCO_3$ & $Cd_3\ (PO_4)_2$) [Kabata-Pendias & Pendias, 1992]. Mobility of Cd in alkaline soils is slightly reduced at very alkaline pH due formation of $CdOH^+$, which is not readily adsorbed; Cd is most mobile at pH 4.5-5.5 [Kabata-Pendias & Pendias, 1992]. The present study did not detected cadmium in agriculture soil while the other soils and sediments were not investigated for Cd level.

### 7.3.4 Arsenic (As)

Arsenic is uniformly available in all rock systems (0.5-2.5 ppm) with the exception of organic rich shales, which have (5-13 ppm), [Kabata-Pendias & Pendias, 1992]. Arsenic is present at level of <1.0-95 ppm in world soils [Kabata-Pendias & Pendias, 1992], but the background level in the topsoils is typically low but generally higher than that of the parent material [Norrish, 1975] and infrequently exceeds the threshold of contamination in soils of 15 ppm [NRCC 1978b] and 40 ppm [Eduardo et al., 2010; Alvarenga, 2006]. Arsenic minerals and compounds are soluble, but there is limited mobility in soil because it is adsorbed by hydroxides, clays and organic matter [Kabata-Pendias & Pendias, 1992] and retained by iron oxides [Norrish, 1975]. Thus the As mobility is highest in sandy soils and lowest in fine textured soils and those high in iron [NRCC, 1978b], solubility of As is also affected by pH that result in leaching in acid and sandy soils [NRCC, 1978b]. Unlike most of the trace elements, the inorganic form of As are more mobile and more toxic than the organic forms [NRCC, 1978b; Kabata-Pendias & Pendias, 1992]. The As concentrations in cold arid agriculture soil were determined to range from 1.88-27.03 ppm and total mean content about 8.8 ppm in only some studied sampling sites that were within the normal range of world soils [Kabata-Pendias & Pendias, 1992] and also below the threshold limit [NRCC 1978b; Eduardo et al., 2010; Alvarenga, 2006]. Arsenic content is related to soil texture as well as amount and characteristics of shale materials included in the soil parent material. Higher concentration of As in soil may be due to the irrigation water coming from the ground water through the deep bore well in the study sites, in India groundwater is the main causes of As contamination in soils used for the agriculture purposes and ultimately pollute whole food chain of the ecosystem. Arsenic can be absorbed through roots of foliage and toxicity can occur whenever the exchange capacity has been exceeded, regardless of actual soil As level [NRCC, 1978b].

### 7.3.5 Lead (Pb)

The total range of Pb in world soils is 3-189 ppm with a range in mean of 10-67 ppm and an overall average level of 32 ppm [Kabata-Pendias and Pendias, 1992] and threshold limit is given in Table 7.1. Whereas the Pb content in remote area soils found to be ranged from 10-30 ppm, although the levels in other soils are higher as 30-100 ppm [Davies, 1990]. In the present study, Pb was not detected in agriculture soil. Pb occurs as a sulfide in rocks and replaces K, Ba, Sr and Ca in minerals [Norrish, 1975]. Lead occurs as a sulfide in rocks and replaces K, Ba, Sr and Ca in minerals [Norrish, 1975]. The major presence of Pb occurs in argillaceous sediments (20-40 ppm) and shales (18-25 ppm) while the amounts are also high in felsic rocks (15-24 ppm) further mentioned in Table 7.3, [Kabata-Pendias and Pendias, 1992]. The occurrence of lead in soils mainly depends on soil bedrock origin, deposition level, from industry and transport means as well as from utilization of different kinds of industrial wastes and sewage sludge as fertilizer [Kabata Pendias & Pendias, 1999].

**Table 7.3:** Average geochemical backgrounds (ppm) of heavy metals in earth's crust and rock systems [Garrett, 1998]

| Earth's crust & rock types | Pb | Cd | Cr | Ni | As | Cu |
|---|---|---|---|---|---|---|
| Earth's crust | | | | | | |
| [Taylor, 1964] | 13 | 0.2 | 100 | 75 | 2 | 55 |
| - | 12 | 0.2 | 110 | 89 | 2 | 63 |
| Upper continental crust | | | | | | |
| [McLennan, 1992] | 20 | 0.1 | 35 | 20 | 1.5 | 25 |
| - | 13 | 0.2 | 77 | 61 | 1.7 | 50 |
| Igneous Rocks | | | | | | |
| Ultramafic [Turekian & Wedepohl, 1961] | 1 | 0.1 | 1600 | 2000 | 1 | 10 |
| Mafic [Turekian & Wedepohl, 1961] | 6 | 0.2 | 170 | 130 | 2 | 87 |
| Intermediate [Turekian & Wedepohl, 1961] | 15 | 0.1 | 22 | 15 | 2 | 30 |
| Felsic [Turekian & Wedepohl, 1961] | 19 | 0.1 | 4 | 5 | 1 | 10 |
| Sedimentary Rocks | | | | | | |
| Sandstone [Faust and Aly, 1981] | 14 | 0 | 120 | 3 | 1 | 15 |
| Limestone [Faust and Aly, 1981] | 16 | 0.1 | 7 | 13 | 2 | 4 |
| Shale [Faust and Aly, 1981] | 80 | 0.2 | 423 | 29 | 9 | 45 |
| Black Shale [Dunn, 1990] | 15 | 4 | 18 | 68 | 22 | 50 |
| [Vine & Tourtelot, 1970] | 100 | - | 700 | 300 | - | 200 |

## 7.5 Conclusion

Results revealed that, Ni and Cr concentrations in agriculture soil were measured above the threshold limit, so this may cause health risk to the living beings and ecology at this cold arid microclimate. Risk assessment of heavy metal pollution for terrestrial environments is often based on their total soil and sediment concentrations; heavy metal contamination in soil is a major concern because of their toxicity and threat to the life of plants, animals, human beings and environment.

# CHAPTER VIII

# To know physico-chemical properties and heavy metals status in irrigation, stagnant (pond) and river (Indus) water of cold desert high altitude region

## Abstract

Physico-chemical properties and heavy metals of any aqueous ecosystems have profound role in their water quality and their suitability for drinking & irrigation and for environment health. The present study was conducted with the objective to investigate the physico-chemical properties and heavy metals distribution in aquatic ecosystems of cold desert high altitude (CDHA) microclimate in India. The study was done in Leh-Ladakh, a high altitude, cold arid microclimate of India lies in Tibetan plateau. The water samples were collected from Indus river water, stagnant water (ponds) and irrigation water resources spread over and around the agriculture fields, samples were analyzed for physico-chemical parameters viz. pH, electrical conductivity (EC), Salinity, Total dissolved salts (TDS), turbidity, chemical oxygen demand (COD) and heavy metals viz. Arsenic (As), Cadmium (Cd), lead (Pb), Chromium (Cr) and Nickel (Ni). The results revealed that the total mean values of pH (7.58±0.04), EC (243.78±18.05 µS/cm), Salinity (0.12±0.01%), TDS (121.519.75 mg/l), turbidity (1.17±0.22 NTU) and COD (31.45±0.73 mg/l) of Indus river water were determined, while of irrigation water, pH (7.43±0.05), EC (231.86±11.00µS/cm), Salinity (0.11±0.01%), TDS (113.31±5.48 mg/l), turbidity (0.85±0.11NTU) and COD (29.74±0.49 mg/l) and of stagnant water pH (7.46±0.03), EC (233.14±11.41µS/cm), Salinity (0.12±0.01%), TDS (115.03±5.78 mg/l), turbidity (0.67±0.13 11NTU) and COD (29.65±0.57 mg/l) were reported. Variance in the range of heavy metals of Indus river water were determined to 0.001-0.099 ppm (As), 0.019-0.045 ppm (Cd), 0.039-228 (Pb), 0.020-0.035 ppm (Cr) and 0.001-0.051 (Ni), while in irrigation water, As (0.006-0.201 ppm), Cd (0.012-0.036 ppm), Pb (0.043-0.275 ppm), Cr (0.019-0.275 ppm) and Ni (0.001-0.062 ppm); and in stagnant water, As (0.002-0.121ppm), Cd (0.019-0.049 ppm), Pb (0.039-0.229 ppm), Cr (0.020-0.220 ppm) and Ni (0.001-0.043 ppm) were estimated. Our results revealed that As, Pb and Cd are observed above the maximum permissible limit and can pose the health hazards for human and animals, therefore the long term uses of this water for drinking purposes to humans and animals should be avoided and it require suitable measures to minimize their long exposure.

**Key words:** Physico-chemical properties, Heavy metals, Indus river water, irrigation water, Cold desert, stangnant water

## 8.1 Introduction

Exceptional population growth, changing global climate, rapid urbanization, expansion of infrastructure, migration, land conversion and pollution translate into changes in fluxes, pathways and stores of water from rapidly melting glaciers to the decline of groundwater due to overexploitation. Pollution of heavy metals in aquatic ecosystem is growing at an alarming rate and has become an important problem worldwide [Fernandez and Olalla, 2000]. The toxicity of heavy metals has long been concerned since it is very important to the health of people and ecology. They exert a deleterious effect on fauna and flora of lakes and streams [Sayari, et al., 2005] change biogeochemical and geochemical cycles of heavy metals [Azimi et al., 2003; Friedland & Miller, 1999], environmental health [Kabata-Pendias and Pendias, 1992], aquatic habitats especially on river systems [Thornton and Dise, 1998], stress the biotic community [Baldantoni et al., 2004] and limiting diversity of aquatic organisms and plants [Samanta et al., 2005; Das et al.,1997]. The presence of heavy metals in water results from weathering of soils and rocks with its products being transported by air and water, the main natural source of heavy metals in waters is chemical weathering of minerals and soil leaching. The primary sources of heavy metal pollution in lakes are input from rivers, sediments and the atmosphere (Panda et al., 2002). Anthropogenic activities like mining, ultimate disposal of treated and untreated waste effluents containing toxic metals [Amman et al., 2002] from different industries viz. tannery, steel plants, Bhatery industries, thermal power plants etc. and also the indiscriminate use of heavy metal containing fertilizers and pesticides in agriculture [Ross, 1994]. Excessive use of fertilizers, pesticides, sewage sludge or irrigation with residual waters causes of contamination of raw foodstuffs [Demirozu & Saldamli, 2002]. As a result of the soil, atmosphere, underground and surface water pollution, our foods and beverages are getting contaminated with heavy metals [Krejpcio et al., 2005]. Anthropogenic metals may consistently retain within the water bodies or may be taken up by organisms such as plankton, fish and finally transferred to humans [Ahmad et al., 2009]. Atmospherically driven heavy metals have been shown to significantly contaminate soil and vegetables causing a serious risk to human health when plant based foodstuffs are consumed [Pandey & Pandey, 2009a; Voutsa et al. 1996]. Heavy metals enter water bodies from both natural and anthropogenic sources: atmospheric deposition, weathering of rocks, erosion, runoff, untreated sewage, agricultural activities and industries and mining [Ljung, 2001].

Metals for example, are introduced into aquatic system through several ways which include, weathering of rocks and leaching of soils, dissolution of aerosol particles from the atmosphere and from several human activities, including mining, processing and the use of metal based materials [Ipinmoroti and Oshodi, 1993; Asaolu et al., 1997]. Metals after entering the water many be taken up by fauna and flora and eventually, accumulated in marine organisms that are consumed by human being [Asaolu et al., 1997]. The increased use of metal-based fertilizer in agricultural revolution of the government could result in continued rise in concentration of metal pollutions in fresh water reservoir due to the water run-off. Also faecal pollution of drinking water causes water born disease which has led to the death of millions of people both in cities and villages (Asaolu, 1998). The discharge of these wastes may affect the aquatic of such river or adversely and alter the chemical composition of the river [Adewoye, 1998]. Water quality characteristic of aquatic environment arise from a multitude of physical, chemical and biological interactions [Dee, 1989].

Irrigation water has been shown to provide the main route for dietary intake of heavy metals through agricultural produce [Sharma et al., 2007]. Heavy metals may not always be in a strong relationship between the concentrations of trace elements in soil and plants [Siegel, 2002], but there always exists a strong relationship between their concentrations in irrigational water and plants [Ahmad & Goni, 2009]. Most heavy metals are supposed to accumulate in aquatic animals and pass their toxic effects onto the upper links of the trophic chain, including human beings [Sindhe and Kulkarni, 2005; Yigit and Altindag, 2006]. Rivers are a dominant pathway for metals transport [Miller et al., 2003] and become significant pollutants of many small riverine systems (Dassenakis et al., 1998]. In aquatic system, metal toxicity can be influenced by various abiotic environmental factors such as oxygen, hardness [Ghillebaert et al., 1995], pH, alkalinity and temperature [Adhikari et al., 2006]. All heavy metals exist in aqueous system as colloidal, particulate or dissolved phases [Osmond et al., 1995]. The behavior of metals in natural waters is a function of the substrate sediment composition, the suspended sediment composition and the water chemistry [Osmond et al., 1995]. Heavy metals do not exist in soluble forms for a long time in waters; they are present mainly as suspended colloids or are fixed by organic and mineral substances [Kabata-Pendias and Pendias, 2001]. As heavy metals cannot be degraded, they are deposited, assimilated or incorporated in water, sediment and aquatic animals [Linnik and Zubenko, 2000], thus causing heavy metal pollution in water bodies. During their transport, the trace metals undergo numerous changes in their speciation due to dissolution, precipitation, sorption and complexation phenomena [Dassenakis et al., 1997; Akcay et al., 2003] which affect their behavior and bioavailability [Nicolau et al., 2006].

Acute and chronic exposure to heavy metals causes hematological, brain damage, anemia and kidney malfunctioning [Zheng et al., 2008]; dermal changes, respiratory, pulmonary, cardiovascular, gastrointestinal, hematological, hepatic, renal, neurological, developmental, reproductive, immunologic, genotoxic, mutagenic and carcinogenic effects [Mandal & Suzuki 2002]; carcinogenesis-induced tumor promotion [Schwartz 1994]; edema of eyelids, tumor, congestion of nasal mucous membranes and pharynx, stuffiness of the head and gastrointestinal, muscular, reproductive, neurological and genetic malfunctions caused by some of these heavy metals have been documented [Tsuji and Karagatzides, 2001]. Cu containing dust is manifested by metal fume fever [Krizek et al., 1997]; Zn toxicity causes electrolyte imbalance, nausea, anaemia and lethargy [Onionwa et al., 2001]; Cd causes kidney damage, act as carcinogenic element [Krejpcio et al., 2005; Rubio et al., 2006]. Cold desert high altitude (CDHA) water systems are very sensitive to climate change because numerous hydro-ecological processes react to even a small change in climate. The cryospheric or subzero temperature mechanisms and components, that extensively affect the water cycle of rivers, lakes, ponds; the habitat characteristics of these freshwater systems; and the flora and fauna that occupy them. The nature and severity of climate and weather have a strong impact on the hydrology and ecology of CDHA water ecosystems. Therefore, monitoring these metals is important for safety assessment of the environment, human and animal health, considering the spatial and temporal variations in heavy metal content and also to evaluate the water quality with respect to drinking to human and animals and agricultural irrigation purposes.

## 8.2 Material and methods

### 8.2.1 Location and study conditions

Present study was conducted in Leh district of Ladakh division lies in trans-Himalayan region in India. Ecologically Ladakh region lays in Tibetan Plateau is a cold arid region under the rain shadow of the Himalayas. Since the region lies in the rain shadow it became one of the cold driest (cold arid) place on the earth and considered as sub-arctic region. Geographically, Ladakh is one of the divisions of Jammu and Kashmir province in India, divided into two districts namely Kargil and Leh. Leh is situated in the eastern Ladakh Plateau and come under cold hyper arid ecosystem (ESR) surrounded by the Indus and Zanskar Rivers. Leh district is situated between $32^0$ to $36^0$N latitude and $75^0$ to $80^0$E longitude and at an altitude ranging from 9666 to 19666 ft. amsl. The study area lies between $33^0$59’362 to $34^0$17’722 N latitude and $077^0$12’023 to $077^0$45’669 E longitude and with at an elevation ranging from 9000 to 13000 ft. amsl. Annual temperature in this region ranges from -$30^0$C to +$40^0$C. Annual minimum and maximum average temperature is -$1.46^0$C and +$13.48^0$C, respectively and annual minimum and maximum average relative humidity is 24.70 and 39.03%. Annual precipitation is less than 100 mm mostly in form of snowfall. Due to high altitude and low humidity, the radiation level is amongst the highest in the world (up to 6-7 Kwh/mm). Longer photoperiod (>12 hrs) and about 330 sunny days in a year and only one cropping season in a year (span from May to September) are typical characteristics of this region. These conditions make the agriculture and allied practices very tough nevertheless, by diverting glacial fed rivers into stone built terraces, gathering soil through sedimentation, enriching the soil with organic manure and other practices by which local farmers are able to cultivate staples under such harsh climatic conditions in this region. Cultivation and habitations in the Ladakh region are mostly confined to the river valleys, like Indus valley, Nubra-Shyok valley, Shingo- Suru valley (Dras-Suru-Wakha valley) and Zanskar valley. Some villages are also situated on the low lying mountain slopes and around the rivers in the Chang-Chenmo, Ladakh and Zanskar ranges. The villages under present study are situated in the Indus valley, Shingo-Suru valley and in the regions of Zanskar range. In Leh district, it is limited to 99.7 mm as normal annual. Winter precipitation is also low, at about 40 to 50 mm. The average annual rainfall in Kargil district is recorded 250 to 300 mm.

### 8.2.2 Water sample collection

Water samples were collected from Leh-Ladakh area scattered over a 70 kilometers of range where most of the population is residing. Indus River water was collected from seven sites and from each site six water samples were collected. Irrigation and stagnant water were collected from eleven sites, and from each site six samples were collected from each site. Water samples were collected in acid pretreated plastic bottles, about 1.0 liter of water sample was collected and immediately 2-3 drops of pure toluene was added as a preservative. Samples were immediately taken into the laboratory and stored at $4^0$C in frost chamber for further analysis.

### 8.2.3 Chemical and reagents

For the laboratory analysis of various water quality parameters, chemical and reagents were GR grade purchased from Merck Germany and some purchased from Sigma Aldrich United State of America were AR grade. Standards used in the estimation of heavy metals (As, Cd, Pb, Cr and Ni) that were single and multielement, purchased from Merck, Germany.

### 8.2.4 Laboratory methods

For the water quality test the parameters viz. pH, electrical conductivity, salinity, total dissolved salts (TDS), chemical oxygen demand (COD), turbidity were estimated. For the pH measurement, Orion 420 a (Thermo Orion, USA) pH meter was used with a glass electrode. In order to minimize the change in pH due to interaction with the atmospheric $CO_2$ measurement was done at time of sample collection. For the TDS measurement, by dipping the TDS electrode in standard solution and calibrated at 500 mg/l, after the calibration samples were tested. COD was estimated by using the Closed Reflux, Titration method. For the heavy metal estimation, all the water samples taken from the frost chamber and prepared for analysis as 50 ml of water sample was taken in 500 ml of conical flask and added 10 ml of 70 % $HNO_3$ and kept at $80^0$C for 30 min evaporated upto the 10 ml of sample, cooled and made volume 50 ml with Milli Q water and these samples were used for heavy metals analysis [APHA, 1989]. Heavy metals (As, Cd, Pb, Cr and Ni) were estimated by ICP-OES (Optima 7000 DV, Perkin Elmer and United State of America).

### 8.2.5 Statistical analysis

Data generated through the study were analyzed for mean and standard error (SE). Significance level ($P<0.05$) was calculated among the different water resources (stagnant water & irrigation water) by one way ANOVA using the SPSS statistical software, (11.5 version, SPSS Inc., USA (SPSS, 1999).

## 8.3 Results

### 8.3.1 Physico-chemical properties of irrigation water

Salinity of irrigation water was varied significantly (P<0.05) from 0.06±0.02 to 0.20±0.00% whereas, total average content was determined to 0.11±0.01% from studied sampling sites at cold arid region (Table 8.1). TDS is very important parameter of water quality determinant ranges from 40.84±0.59 to 204.66±12.02 mg/l while, total mean content of salinity was observed to 113.31±5.48 mg/l. Turbidity of the irrigation water varied from zero to 1.80±0.37 NTU and average value was reported 0.85±0.11 NTU (Table 8.1). The chemical oxygen demand (COD) of all irrigation water from all sampling sites was varied from 25.08±0.62 to 33.56±1.74 mg/l whereas total average value was reported to 29.74±0.49 mg/l, most of the sampling site were observed significantly (P<0.05) different with each other (Table 8.1).

**Table 8.1:** Physico-chemical properties of irrigation water from cold desert high altitude region

| Study sites | pH | EC (µS/cm) | Salinity (%) | TDS (mg/L) | Turbidity (NTU) | COD (mg/L) |
|---|---|---|---|---|---|---|
| 1 | $7.61^{a}$±0.08 | $317.60^{de}$±54.93 | $0.14^{b}$±0.02 | $157.56^{ef}$±29.87 | 0.00±0.00 | $26.92^{abc}$±1.41 |
| 2 | $7.67^{a}$±0.02 | $418.20^{f}$±11.98 | $0.20^{c}$±0.00 | $204.66^{g}$±12.02 | $0.60^{a}$±0.24 | $30.25^{abcd}$±0.89 |
| 3 | $7.64^{a}$±0.07 | $202.50^{bc}$±9.31 | $0.10^{ab}$±0.00 | $96.38^{bc}$±5.61 | $1.20^{a}$±0.80 | $26.20^{ab}$±1.24 |
| 4 | $7.57^{a}$±0.10 | $210.66^{bc}$±6.90 | $0.10^{ab}$±0.00 | $101.22^{c}$±2.63 | $0.40^{a}$±0.40 | $36.06^{e}$±0.82 |
| 5 | $7.58^{a}$±0.04 | $329.20^{e}$±43.14 | $0.14^{b}$±0.02 | $150.86^{def}$±22.14 | $0.60^{a}$±0.40 | $25.79^{ab}$±0.62 |
| 6 | $7.57^{a}$±0.01 | $237.40^{cde}$±6.58 | $0.10^{a}$±0.00 | $113.92^{cde}$±2.92 | $0.60^{a}$±0.40 | $30.54^{bcd}$±2.18 |
| 7 | $7.71^{a}$±0.03 | $195.20^{bc}$±18.86 | $0.10^{ab}$±0.00 | $102.36^{c}$±1.37 | $1.20^{a}$±0.37 | $29.39^{abcd}$±2.38 |
| 8 | $7.66^{a}$±0.02 | $226.00^{bcd}$±4.72 | $0.10^{ab}$±0.00 | $108.94^{cd}$±2.30 | $1.80^{b}$±0.37 | $28.85^{abcd}$±2.06 |
| 9 | $7.67^{a}$±0.02 | $245.98^{cde}$±77.19 | $0.14^{b}$±0.02 | $165.46^{fg}$±29.82 | $1.20^{a}$±0.80 | $31.68^{cde}$±0.66 |
| 10 | $7.59^{a}$±0.02 | $231.60^{bcde}$±6.21 | $0.12^{b}$±0.02 | $108.52^{cd}$±1.33 | $0.80^{a}$±0.49 | $30.43^{bcd}$±0.26 |
| 11 | $7.55^{a}$±0.03 | $242.60^{cde}$±7.68 | $0.12^{b}$±0.02 | $116.06^{cde}$±3.52 | $0.80^{a}$±0.37 | $31.65^{cde}$±2.10 |
| Mean | 7.43±0.05 | 231.86±11.00 | 0.11±0.01 | 113.31±5.48 | 0.85±0.11 | 29.74±0.49 |

Value (Mean±SE, N=6) bearing different superscripts differ significantly (P<0.05) between the row.

### 8.3.2 Physico-chemical properties of stagnant water (ponds)

The physico-chemical parameters from cold desert high altitude microclimate are presented in Table 8.2. Results of our investigation revealed that, pH of all sampling locations ranged from 7.19±0.06 to 7.77±0.05 whereas; total average value was reported to 7.46±0.03. Total mean content of EC was reported to 233.14±11.41 µS/cm while the range differed from 119.40±5.46 to 324.60±42.65 µS/cm in all study locations (Table 8.2). The values of salinity in stagnant water were ranged from 0.06 ±0.02 to 0.16±0.02% although; total mean content was reported to 0.12±0.01%. On the other hand, TDS was examined to be ranged from 57.00±2.63 to 168.44±22.24 mg/l, while the average value was 115.03±5.78 mg/l. The total mean contents of turbidity and COD were reported to 0.67±0.13 NTU and 29.65±0.57 mg/l respectively, while the range varied from 0.00 to 1.80±0.92 NTU and 25.30±0.73 to 33.78±1.65 mg/l respectively (Table 8.2).

**Table 8.2**: Physico-chemical properties of stagnant water (pond) of cold desert high altitude region

| Study sites | pH | EC (µS/cm) | Salinity (%) | TDS (mg/L) | Turbidity (NTU) | COD (mg/L) |
|---|---|---|---|---|---|---|
| 1 | $7.52^{bcde}$±0.02 | $278.34^{bc}$±48.73 | $0.14^{bc}$±0.02 | $138.42^{bcd}$±25.1 | $0.64^{abc}$±0.39 | $30.68^{ab}$±2.09 |
| 2 | $7.77^{e}$±0.05 | $259.40^{bc}$±10.51 | $0.10^{abc}$±0.00 | $118.36^{bc}$±4.60 | $0.80^{abc}$±0.37 | $33.78^{b}$±1.65 |
| 3 | $7.40^{abcd}$±0.24 | $236.98^{bc}$±21.58 | $0.12^{abc}$±0.02 | $121.24^{bc}$±10.6 | $0.40^{abc}$±0.24 | $29.16^{ab}$±3.14 |
| 4 | $7.31^{abc}$±0.17 | $209.48^{ab}$±27.08 | $0.12^{abc}$±0.02 | $105.66^{b}$±11.92 | $0.20^{ab}$±0.20 | $25.30^{a}$±0.73 |
| 5 | $7.63^{cde}$±0.03 | $324.60^{e}$±42.65 | $0.16^{c}$±0.02 | $168.44^{d}$±22.24 | $0.60^{abc}$±0.24 | $32.09^{ab}$±0.56 |
| 6 | $7.48^{abcde}$±0.03 | $293.00^{bc}$±17.06 | $0.14^{bc}$±0.02 | $139.86^{cd}$±8.77 | $0.60^{abc}$±0.24 | $28.55^{ab}$±0.96 |
| 7 | $7.56^{cde}$±0.03 | $243.80^{bc}$±5.54 | $0.12^{abc}$±0.02 | $117.72^{bc}$±2.86 | $1.80^{c}$±0.92 | $27.65^{ab}$±2.23 |
| 8 | $7.70^{de}$±0.05 | $307.86^{bc}$±66.81 | $0.14^{bc}$±0.02 | $164.2^{cd}$±28.98 | $1.60^{bc}$±0.81 | $29.17^{ab}$±1.85 |
| 9 | $7.19^{a}$±0.06 | $119.40^{a}$±5.46 | $0.08^{ab}$±0.02 | $57.00^{a}$±2.63 | $0.04^{a}$±0.02 | $29.40^{ab}$±2.50 |
| 10 | $7.19^{a}$±0.06 | $119.40^{a}$±5.46 | $0.08^{ab}$±0.02 | $57.00^{a}$±2.63 | $0.04^{a}$±0.02 | $29.40^{ab}$±2.50 |
| 11 | $7.22^{ab}$±0.07 | $119.52^{a}$±5.30 | $0.06^{a}$±0.02 | $56.58^{a}$±2.52 | 0.00±0.00 | $29.86^{ab}$±2.08 |
| Mean | 7.46±0.03 | 233.14±11.41 | 0.12±0.01 | 115.03±5.78 | 0.67±0.13 | 29.65±0.57 |

Value (Mean±SE, N=6) bearing different superscripts differ significantly (P<0.05) between the row

### 8.3.3 Physico-chemical parameters of Indus river water

Physico-chemical parameters of Indus river water were presented in Table 8.3. The results revealed that, the total mean values observed to be pH (7.58±0.04), EC (243.78±18.05 µS/cm), salinity (0.12±0.01%), TDS (121.519.75 mg/l), turbidity (1.17±0.22 NTU) and COD

(31.45±0.73 mg/l) in Indus river water (Table 8.3) the results shows that the pH of river water varied from 5.76±0.06 to 5.76±0.06 while the average value is 7.43±0.05, even though the sampling sites, 13 & 15 were differ significantly ($P<0.05$) with each other, whereas other sampling locations were non-significant ($P<0.05$) with each other. EC ranges from 86.16±1.72 to 418.20±11.98 µS/cm while the average value was 231.86±11.00 µS/cm, most of the EC values from different locations differed significantly ($P<0.05$) with each other (Table 8.3).

**Table 8.3:** Physico-chemical properties of Indus river water from cold desert high altitude microclimate

| Study sites | pH | EC (µS/cm) | Salinity (%) | TDS (mg/L) | Turbidity (NTU) | COD (mg/L) |
|---|---|---|---|---|---|---|
| 1 | $7.38^{ab}$±0.15 | $130.34^{a}$±5.39 | $0.06^{a}$±0.02 | $61.32^{a}$±2.43 | $0.40^{a}$±0.24 | $28.21^{a}$±1.88 |
| 2 | $7.26^{a}$±0.06 | $224.40^{b}$±4.14 | $0.10^{ab}$±0.00 | $111.94^{b}$±1.48 | 0.00±0.00 | $29.36^{ab}$±2.37 |
| 3 | $7.51^{bc}$±0.09 | $410.20^{c}$±29.74 | $0.20^{c}$±0.00 | $210.40^{c}$±14.77 | $1.60^{ab}$±0.51 | $30.25^{ab}$±1.51 |
| 4 | $7.87^{d}$±0.02 | $195.80^{ab}$±12.45 | $0.10^{ab}$±0.00 | $94.44^{ab}$±5.88 | $1.80^{b}$±0.37 | $32.76^{ab}$±1.53 |
| 5 | $7.72^{cd}$±0.05 | $206.26^{ab}$±6.40 | $0.12^{b}$±0.02 | $97.44^{ab}$±3.63 | $2.00^{b}$±0.95 | $34.70^{b}$±2.27 |
| 6 | $7.64^{cd}$±0.07 | $184.28^{ab}$±13.11 | $0.12^{b}$±0.02 | $89.14^{ab}$±6.33 | $1.00^{ab}$±0.45 | $33.33^{ab}$±0.41 |
| 7 | $7.66c^{d}$±0.04 | $355.20^{c}$±54.24 | $0.14^{b}$±0.02 | $185.92^{c}$±28.43 | $1.40^{ab}$±0.75 | $31.54^{ab}$±2.17 |
| Mean | 7.58±0.04 | 243.78±18.05 | 0.12±0.01 | 121.51±9.75 | 1.17±0.22 | 31.45±0.73 |

Value (Mean±SE, N=6) bearing different superscripts differ significantly ($P<0.05$) between the row

### 8.3.4 Heavy metals concentration in irrigation water

Various heavy metals concentration in irrigation water from cold desert high altitude microclimate have been investigated and presented in Table 8.4. Results from our present study revealed that, Arsenic was ranged from 0.006 to 0.201ppm and total average concentration was investigated to 0.075±0.006 ppm, whereas one way ANOVA analysis revealed that, significantly ($P<0.05$) higher concentration of As was estimated at site 8 (0.102±0.005 ppm) and the lower content at site 11 (0.016±0.005 ppm) (Table 8.4). On the other hand, total average contents of cadmium and lead were estimated to 0.024±0.001 and 0.111±0.006 ppm respectively, whereas, their range differed from 0.012 to 0.036 and 0.043 to 0.275 ppm respectively. Statistical analysis revealed that, significantly ($P<0.05$) higher and lower values of Cd, and Pb were estimated at site 11 (0.031±0.002 ppm), site1 (0.020±0.000 ppm); site 2 (0.129±0.005 ppm), site 11 (0.069±0.002 ppm) respectively. Chromium was significantly ($P<0.05$) higher reported in sampling site 1 (0.030±0.005 ppm), whereas, lower in sampling site 3 & 4 (0.021±0.000 ppm), the total mean Cr content was reported to 0.024±0.000 ppm while, their range varied from 0.019 to 0.275 ppm. Nickel contents in our present investigation ranged from 0.001 to 0.062 ppm and total mean concentration was 0.016±0.002 ppm (Table 8.4).

**Table 8.4:** Heavy metals concentration (ppm) in irrigation water of cold desert high altitude region

| Study sites | As | Cd | Pb | Cr | Ni |
|---|---|---|---|---|---|
| 1 | $0.031^{ab}±0.009$ | $0.020^{b}±0.000$ | $0.058^{ab}±0.003$ | $0.030^{b}±0.005$ | $0.030^{c}±0.004$ |
| 2 | $0.038^{bc}±0.007$ | $0.025^{cdef}±0.001$ | $0.129^{d}±0.005$ | $0.023^{a}±0.002$ | $0.002^{a}±0.000$ |
| 3 | $0.051^{cd}±0.002$ | $0.023^{c}±0.000$ | $0.105^{cd}±0.004$ | $0.021^{a}±0.001$ | $0.003^{a}±0.000$ |
| 4 | $0.064^{d}±0.003$ | $0.026^{b}±0.001$ | $0.100^{cd}±0.007$ | $0.021^{a}±0.000$ | $0.001^{a}±0.000$ |
| 5 | $0.086^{ef}±0.008$ | $0.025^{cde}±0.001$ | $0.091^{bcd}±0.004$ | $0.022^{a}±0.001$ | $0.001^{a}±0.000$ |
| 6 | $0.094^{efg}±0.002$ | $0.027^{def}±0.001$ | $0.096^{bcd}±0.006$ | $0.023^{a}±0.000$ | $0.001^{a}±0.001$ |
| 7 | $0.101^{fg}±0.005$ | $0.027^{def}±0.000$ | $0.092^{bcd}±0.002$ | $0.023^{a}±0.000$ | $0.002^{a}±0.000$ |
| 8 | $0.102^{fg}±0.005$ | $0.028^{f}±0.000$ | $0.097^{bcd}±0.002$ | $0.022^{a}±0.001$ | $0.001^{a}±0.000$ |
| 9 | $0.081^{e}±0.002$ | $0.028^{ef}±0.001$ | $0.083^{abc}±0.004$ | $0.023^{a}±0.000$ | $0.003^{a}±0.000$ |
| 10 | $0.064^{d}±0.002$ | $0.027^{def}±0.000$ | $0.088^{bc}±0.001$ | $0.023^{a}±0.000$ | $0.002^{a}±0.001$ |
| 11 | $0.016^{a}±0.005$ | $0.031^{g}±0.002$ | $0.069^{abc}±0.002$ | $0.023^{a}±0.000$ | $0.015^{b}±0.000$ |
| Mean | 0.075±0.006 | 0.024±0.001 | 0.111±0.006 | 0.024±0.000 | 0.016±0.002 |
| Range | 0.006-0.201 | 0.012-0.036 | 0.043-0.275 | 0.019-0.275 | 0.001-0.062 |

Value (Mean±SE, N=6) bearing different superscripts differ significantly (P<0.05) between the row.

### 8.3.5 Heavy metals concentration of stagnant (ponds) water

Arsenic concentration in sampling sites 1, 2, and 11 did not detected while most of other sites differ significantly (P<0.05) with each other, as their range varied from 0.002 to 0.121 ppm and total mean content was estimated to 0.034±0.004 ppm. One way ANOVA analysis disclosed that, significantly (P<0.05) higher value of As was estimated at site 4 (0.100±0.008 ppm) and lower at site 10 (0.021±0.002 ppm) (Table 8.5). Cadmium and lead were examined significantly (P<0.05) higher at site 11 (0.034±0.005ppm) and site 8 (0.171±0.035ppm) and lower at site 1 (0.020±0.000 ppm) and site 9 (0.050±0.003 ppm) respectively. The total average concentration of Cd was observed to 0.027±0.001 ppm and its range varied from 0.019 to 0.049 ppm, whereas Pb content varied from 0.039 to 0.229 ppm and average value estimated to 0.095±0.005 ppm. Chromium concentration was ranged from 0.020 to 0.220 ppm and total mean content was estimated to 0.030±0.003 ppm. Total average content of Ni was determined to 0.013±0.001 ppm and values ranged from 0.001 to 0.043 ppm in all study sites. The statistical analysis revealed that, significantly higher and lower values of Pb, Cr and Ni were estimated at site 8 (0.171±0.035 ppm), site 9 ($0.050^{a}$±0.003 ppm); site 8 (0.034±0.009 ppm), site 3 (0.021±0.000 ppm) and site 11 (0.026±0.002 ppm), site 5 (0.002±0.001 ppm) respectively (Table 8.5).

**Table 8.5:** Heavy metals concentration (ppm) in stagnant water (pond) of cold desert high altitude region

| Study sites | As | Cd | Pb | Cr | Ni |
|---|---|---|---|---|---|
| 1 | ND | $0.020^{a}$±0.000 | $0.065^{ab}$±0.005 | $0.026^{a}$±0.001 | $0.016^{def}$±0.001 |
| 2 | ND | $0.020^{a}$±0.000 | $0.084^{abc}$±0.010 | $0.030^{b}$±0.002 | $0.021^{fg}$±0.003 |
| 3 | $0.074^{d}$±0.001 | $0.025^{ab}$±0.001 | $0.100^{bcd}$±0.001 | $0.021^{a}$±0.000 | $0.011^{bcd}$±0.008 |
| 4 | $0.100^{f}$±0.008 | $0.029^{bc}$±0.001 | $0.088^{acd}$±0.003 | $0.024^{a}$±0.001 | $0.004^{ab}$±0.001 |
| 5 | $0.087^{e}$±0.003 | $0.028^{abc}$±0.001 | $0.093^{abcd}$±0.002 | $0.034^{b}$±0.004 | $0.002^{a}$±0.001 |
| 6 | $0.049^{c}$±0.002 | $0.028^{abc}$±0.001 | $0.091^{abcd}$±0.002 | $0.023^{a}$±0.001 | $0.003^{ab}$±0.001 |
| 7 | $0.042^{c}$±0.003 | $0.025^{a}$±0.001 | $0.086^{abc}$±0.001 | $0.025^{a}$±0.001 | $0.006^{abc}$±0.000 |
| 8 | $0.021^{b}$±0.005 | $0.031^{bc}$±0.003 | $0.171^{e}$±0.035 | $0.034^{b}$±0.009 | $0.011^{bcd}$±0.002 |
| 9 | $0.042^{c}$±0.002 | $0.026^{ab}$±0.002 | $0.050^{a}$±0.003 | $0.021^{a}$±0.001 | $0.013^{cde}$±0.001 |
| 10 | $0.021^{b}$±0.002 | $0.026^{ab}$±0.001 | 0.052a±0.002 | $0.022^{a}$±0.001 | $0.017^{def}$±0.001 |
| 11 | ND | $0.034^{c}$±0.005 | $0.126^{cd}$±0.004 | $0.028^{b}$±0.001 | $0.026^{g}$±0.002 |
| Mean | 0.034±0.004 | 0.027±0.001 | 0.095±0.005 | 0.030±0.003 | 0.013±0.001 |
| Range | 0.002-0.121 | 0.019-0.049 | 0.039-0.229 | 0.020-0.220 | 0.001-0.043 |

Value (Mean±SE, N=6) bearing different superscripts differ significantly (P<0.05) between the row

### 8.3.6 Heavy metals concentration in Indus river water

Heavy metals concentrations in Indus river water were presented in Table 8.6. Rsults of our study revealed that, Arsenic and cadmium were estimated in all studied sites in this CDHA region, as total mean concentrations of As and Cd were determined to 0.037±0.005 and 0.025±0.001 ppm respectively while their concentrations ranged from 0.001 to 0.099 and 0.019 to 0.045 ppm respectively. The one way analysis disclosed that, significantly (P<0.05) higher and lower values of As and Cd concentrations were estimated at site 4 (0.094±0.002 ppm), site 1 (0.005±0.003 ppm) and at site 3 (0.028±0.004 ppm), site 1 (0.020±0.000 ppm) respectively. On the other hand, total average concentrations of lead and chromium were determined to 0.089±0.009 and 0.024±0.001 ppm respectively while their concentrations ranged from 0.039 to 228 and 0.020 to 0.035 ppm respectively, significanltly higher level of Pb and Cr were estimated at site 3 (0.191±0.011 ppm ) and at site 1 (0.029±0.002 ppm) respectively. Nickel concentration ranged from 0.001 to 0.051 ppm, while total mean concentration was estimated to 0.015±0.002 ppm and significantly higher level was determined at the site 2 (0.035±0.009 ppm) and lower at site 3 (0.003±0.000 ppm), (Table 8.6).

**Table 8.6:** Heavy metal concentration (ppm) in Indus river water of cold desert high altitude microclimate

| Study sites | As | Cd | Pb | Cr | Ni |
|---|---|---|---|---|---|
| 1 | $0.005^{a}$±0.003 | $0.020^{a}$±0.000 | $0.050^{a}$±0.003 | $0.029^{c}$±0.002 | $0.018^{b}$±0.001 |
| 2 | $0.053^{c}$±0.008 | $0.022^{ab}$±0.002 | $0.104^{b}$±0.031 | $0.025^{bc}$±0.001 | $0.035^{c}$±0.009 |
| 3 | $0.023^{ab}$±0.011 | $0.028^{c}$±0.004 | $0.191^{c}$±0.011 | $0.024^{ab}$±0.003 | $0.003^{a}$±0.000 |
| 4 | $0.094^{d}$±0.002 | $0.027^{bc}$±0.000 | $0.108^{b}$±0.006 | $0.024^{ab}$±0.001 | $0.009^{ab}$±0.006 |
| 5 | $0.039^{bc}$±0.007 | $0.027^{bc}$±0.000 | $0.069^{ab}$±0.002 | $0.023^{a}$±0.000 | $0.011^{ab}$±0.000 |
| 6 | $0.039^{bc}$±0.006 | $0.026^{bc}$±0.000 | $0.051^{a}$±0.002 | $0.024^{a}$±0.000 | $0.012^{a}$±0.001 |
| 7 | $0.008^{a}$±0.005 | $0.026^{bc}$±0.000 | $0.051^{a}$±0.004 | $0.021^{a}$±0.000 | $0.015^{ab}$±0.004 |
| Mean | 0.037±0.005 | 0.025±0.001 | 0.089±0.009 | 0.024±0.001 | 0.015±0.002 |
| Range | 0.001-0.099 | 0.019-0.045 | 0.039-228 | 0.020-0.035 | 0.001-0.051 |

Value (Mean±SE, N=6) bearing different superscripts differ significantly (P<0.05) between the row

## 8.4 Discussion

### 8.4.1 Physico-chemical properties of Indus river water

#### 8.4.1.1 pH

Results revealed that the pH values of stagnant (7.43±0.05), Indus river (7.58±0.04) and irrigation waters (7.46±0.03) were about to be similar, found in the permissible range of 6.5 to 8.5 for the irrigation to crops and drinking purposes to human and animals and this pH range indicating a slightly alkaline water, this may be due to the presence of carbonate and bi-carbonates [Ravichandran et al., 2002]. A water pH between 6.0 and 7.0 is normally considered to be the most desirable for irrigation. As it was reported that pH affects the dissolved oxygen level in the water, photosynthesis of aquatic plants, metabolic rates of aquatic organisms and the sensitivity of these organisms to pollution, parasites and disease [FWPCA, 1968]. A change in water pH can also affects the aquatic life indirectly by altering other aspects of water chemistry [Schlesinger, 1991].

**8.4.1.2 Turbidity (NTU)**

The present study shows the turbidity of aquatic ecosystems (Indus river, irrigation and stagnant waters) were in normal range as the permissible limit is concerned, WHO [2006] prescribed the highest desirable limit 5.0 NTU and maximum permissible limit 25.0 NTU for the irrigation to crops and drinking purpose to human and animals, further the desirable limit of 5 NTU and permissible limit (10 NTU) for the drinking water to the human beings.  So on the basis of turbidity water collected from various locations of cold arid region is investigated to found well for all the living beings. We know the turbidity is a measure of water clarity, tells the degree to which light entering a column of water is scattered by suspended solids. Suspended solids include things such as mud, algae, detritus and fecal material. Factors which are responsible for low turbidity range over here may be low soil erosion because of low rainfall, low nutrient inputs that stimulate algal blooms, no waste discharge from industry [Schlesinger, 1991]. As we know that the higher turbidity of water causes, less sunlight penetration which results in proportionally decrease in photosynthetic rate of aquatic flora and it again causes decreased oxygen produced by aquatic plants [Merritts, 1998]. Higher turbidity also causes lesser heat absorption from sunlight by suspended materials, lowers water temperature; this reduced the dissolved $O_2$, water can hold [Merritts, 1998; BIS, 1992].

8.4.1.3 Electrical conductivity (µS/cm)

The major water quality guideline for crop productivity is the salinity hazard as measured by EC [Ahmed et al., 2002]. Electrical Conductivity of Indus river water, irrigation water resources and stagnant water were estimated to be 243.78±18.05, 86.16±1.72 to 418.20±11.98 µS/cm, these values are under the permissible limit (<1500 µmohs/cm) for domestic use. BIS [2005] have also recommended a drinking water standard (EC 750 µS/cm) for human and animals. The water resources from cold arid region on the basis of EC in our present study are suitable for irrigation purposes as we know that the EC <250µmhos/cm is considered good and >750 µmhos/cm is unsuitable for the irrigation.  The higher EC causes inability of the plant to compete with ions in soil solution for water, thus less is available to crop plants, usable plant water in soil solution decreases dramatically as EC increases.

#### 8.4.1.4 Salinity (%)

Results from our present study revealed that, the mean level of salinity in Indus River, irrigation and stagnant waters were determined 0.12±0.01, 0.11±0.01 and 0.12±0.01 %, which are safe for all kind of animal's drinking purposes rearing at this region. The main ionic components contributing to salinity of natural sources are most likely the high content of ions such as sodium, chloride and sulphate. These ions in water may have a major impact on a high productivity animal’s acid-base homeostasis. The study of Sanchez et al. [1994] indicated that high intakes of chloride and sulphate affect milk production. Singh and Singh [1995] reported that the higher level of salinity was due to increase in decomposition of organic matters. As the salinity of the soil is increased by the use of water containing appreciable soluble salts, plants have increasing difficulty absorbing water. A primary cause of water salinity is excess sodium as Na accumulates in the soil it can compete with other nutrients for uptake by the plants and may become directly toxic. Excess sodium in natural soil can lead to the loss of soil structure, causing the loss of soil permeability and leading to poor plant growth.

#### 8.4.1.5 Chemical oxygen demand (mg/L)

Most applications of COD determine the amount of organic pollutants found in surface water, making COD a useful measure of water quality. In the present investigation in cold desert high, the COD values ranges from 28.21±1.88 to 34.70±2.27 mg/L (Indus Ricer water), 25.08±0.62 to 32.89±2.04 mg/L (irrigation water); 25.30±0.73 to 33.78±1.65 mg/L (stagnant water) these values are higher than maximum allowed limit of 4.0 mg/L according to USPH Standard and the Tolerance limit of COD for human beings 250 mg/L. COD determination is a measure of the oxygen equivalent of that portion of the organic matter in a sample; COD is useful in specifying toxic condition and presence of biologically resistant substances, measured industrial waste water studies, load of organic pollutants in the industrial waste water and pollution effect. The high value of COD due to high level of pollutants present in water samples.

#### 8.4.1.6 Total dissolved salts (mg/L)

According to BIS [1991] recommendation, water having TDS more than 2000 mg/L are not suitable for drinking purposes and the maximum desirable limit of TDS is 500 mg/L. Salinity problem exists if salt accumulates in crop root zone to a concentration that causes a loss in yield. In the present study the minimum value of total dissolved solids was found in a range of 40.84±0.59 to 204.66±12.02 mg/L, these values are under the desirable limit, means water from the cold desert high altitude ecosystem is good for irrigation purposes to different crops growing over here as well as is suitable for drinking purposes to animals and human beings. The high value of TDS reduces water utility for drinking, irrigation and agriculture purposes [WHO, 1996]. A high content of dissolved solid elements affects the density of water, influences osmoregulation of freshwater in organisms, reduces solubility of gases (like oxygen) and utility, of water for drinking, irrigational and industrial purposes.

### 8.4.2 Heavy metals in various water resources

#### 8.4.2.1 Arsenic (As)

In the present study, our results revealed that elevated level of arsenic in irrigation water from all study sites except site 13, while in stagnant waters the same increasing trend was detected in most of the study locations but the lower concentrations of As determined in Indus River water samples. Levels of As are higher in the aquatic ecosystem may be washed out of arsenic bearing rocks [Edmonds and Francesconi, 1993]. Recently, some other studies reported that the anthropogenic activities such as treatment of agricultural land with arsenical pesticides, treating of wood using chromated copper arsenate, burning of coal in thermal plants power stations and the operations of gold mining have increased the environmental incidence of As and its rate of discharge into freshwater habitat [Pacyna, 1995]. However, in water, particularly ground water, where there are sulfide mineral deposits and sedimentary deposits deriving from volcanic rocks, the concentrations can be significantly elevated [WHO, 2011]. The principal sources of arsenic in ambient air are the burning of fossil fuels, smelting and waste incineration. Arsenic is introduced into water through the erosion and weathering of soil, minerals and ores, from industrial effluents and via atmospheric deposition [Hindmarsh and McCurdy, 1986; Hutton and Symon, 1986]. The average concentration in the earth's crust approximately 2.0 ppm, As generally present in natural waters at the concentrations of $<1–2$ µg/L and its concentrations may be elevated up to 12 ppm in areas containing natural sources [WHO, 2011]. Maximum desirable limit of arsenic in drinking water for human beings is 0.05 ppm [BIS, 2005], 0.01 ppm [WHO, 2011], CCME [2005] guideline (0.025 ppm) to livestock. Recommended limit of Arsenic in water for irrigation for long term (0.10 ppm) and short term uses (2.0 ppm) Rowe and Abdel-Magid [1995]. According to BIS, WHO and As guidelines, water from cold arid ecosystem is not suitable for human as well as for the livestocks prevailed over here and it requires some protection measures, while as water from studied aquatic ecosystems is safe the irrigation purposes to various crops plants in Leh-Ladakh. The potential sources of arsenic for farm animals are food, drinking water, soil and air. Lactating goats consuming a diet containing <10 ppb As had decreased growth rates, decreased milk production, lower birth weights and a higher incidence of mortality.

**8.4.2.2 Nickel (Ni)**

Nickel has been considered to be an essential trace element for human and animal health. Nickel occurs naturally in soils as a result of the weathering of the parent rock [McGrath, 1995]. So in the present study, results disclosed that the nickel concentration in irrigation water monitored below the permissible limit in most of studied, while in Indus River and stagnant waters Ni concentrations determined below the maximum permissible limit (MPL) in most of the studied sites. Some earlier studies reported that, the underlying geology and soil forming processes strongly influence the amount of nickel in soils with higher concentrations reported in clays, silts and fine grained loams relative to coarser grained loams, sandy and peaty soils [kabata-Pendias and Mukherjee, 2007]. The highest concentrations are found in basic igneous rocks with much lower levels found in sedimentary rocks including shales, clays, limestone and sandstones [Kabata-Pendias and Mukherjee, 2007; McGrath, 1995], while in heavy pollution areas, nickel that occurs naturally in groundwater is mobilized [WHO, 2011]. Anthropogenic activity has resulted in the widespread atmospheric deposition of nickel from the burning of oil and coal [McGrath, 1995]. Localized nickel contamination may also occur near a smelter or plating works or be associated with mining activity [ATSDR, 2005]. Agricultural fertilizers, especially phosphates, are also a significant source of nickel in soil but it is unlikely to build-up in soil in the long term from their use [McGrath, 1995]. According to WHO [2004], [USEPA, 1999] and [BIS, 2005] the maximum permissible limit of Ni is 0.02 ppm in drinking water for the human beings. According to CCME [2005], recommended upper safe level of drinking water for livestocks of Ni is 1.0 ppm. The maximum permissible limit for Ni is 0.2 ppm for the irrigation water [Ayers and Westcot, 1976]. It was again reported that the recommended limit of Nickel (Ni) in irrigation water for the health of plants is 0.2 ppm for long term use and 2.0 ppm for short term use, it toxic to a number of plants at 0.5 to 1.0 ppm and reduced toxicity at neutral or alkaline pH [Rowe and Abdel-Magid, 1995]. According to above guidelines, Ni reported in most of the study sites below the permissible limit and somewhere it is above the standard guidelines as per the human health is concerned, this elevated level of Ni may be due to the mobilization of ground water and water sources from igneous rock [Kabata-Pendias and Mukherjee, 2007; McGrath, 1995; WHO, 2011], whereas the water for drinking purpose to livestock and irrigation purpose to various crop plants is considered to be safe.

**8.4.2.3 Lead (Pb)**

Risk of adverse effects associated with lead in drinking water is generally very low; water may contribute to the overall burden of dietary lead in livestock. The permissible limits of [WHO, 2004] for drinking purposes to humans (0.01ppm) and irrigation purpose to different crops (5 ppm) [USEPA, 1999]. CCME [2005] recommended an upper safe level of Pb in water is 0.1 ppm for livestock. Lead concentration was found above the desirable limit in drinking water for human health is 0.01ppm [BIS, 2005]. The present study revealed that, the Pb in studies aquatic ecosystems determined at very high concentrations according to above guidelines, in irrigation water, Pb level is high than River and stagnant waters. According to our predictions water resources from cold desert high altitude are not safe for drinking purposes to human and livestock while it is suitable for irrigation purposes. As it is well known that the lead is used principally in the production of lead acid Bhateries, solder and alloys, it discharged in the surface water through paints, solders, pipes, building material, gasoline etc. Lead is a well known metal toxicant and it is gradually being phased out of the materials that human beings regularly use. Combustion of oil and gasoline account for >50% of all anthropogenic emissions and thus form a major component of the global cycle of lead. Some previous studies reported the elevated level of Pb in water, as atmospheric fallout is usually the most significant source in freshwaters [Moore & Ramamoorthy, 1984]. The concentration of lead in surface water is highly variable depending upon sources of pollution; lead content of sediments; and the pH, salinity and organic matter content of the water. Dissolved lead concentrations in unpolluted freshwaters are generally very low, <0.01 ppm [Fergusson, 1990]. Most lead (over 90%) transported by unpolluted streams is associated with suspended particulate matter [Salomons & Forstner 1995]. Acute toxicity generally appears in aquatic plants at concentration of 0.1–5.0 ppm, initially results in enhanced plant growth, but from a concentration of 5 ppm onwards, this is counteracted by severe growth retardation, discoloration and morphological abnormalities, adversely influence photosynthesis, respiration and other metabolic processes. Acute toxicity of

Pb in invertebrates is reported at the concentration of 0.1–10 ppm [Moore & Ramamoorthy 1984].

#### 8.4.2.4 Chromium (Cr)

Chromium standard in drinking water is 0.05 ppm for humans [WHO, 2004] and recommended standard of Cr concentration for irrigation water is 0.1 ppm [USEPA, 1999], 0.05 ppm [APHA, 1995]. Desirable maximum limit of chromium in drinking water for human health is 0.05 ppm [BIS, 2005]. Recommended limit of Cr in irrigation water is 0.1 ppm in long term use and 1.0 ppm for short term use [Rowe and Abdel-Magid, 1995]. CCME [2005] recommended upper safe level of water to Cr is 0.05 ppm for livestock. In the present study Cr concentration in aquatic ecosystems from the studies areas reported decreased level than the maximum permissible limit for drinking purposes to human and animals and for irrigation to various crop plants and it indicates studied aquatic ecosystems are safe as per the chromium toxicity is concerned in this region. Chromium compounds are used as pigments, mordents and dyes in the textiles and as the tanning agent in the leather, Cr comes in the surface waters from municipal wastes, laundry chemicals, paints, leather and road run off due to tire wear, corrosion of bushings, brake wires and radiators, etc. Chromium is generally more toxic at higher temperatures and its compounds are known to cause cancer in humans [Ember, 1975]. The toxic effects of Cr on plants indicate that the roots remain small and leaves narrow, exhibit reddish brown discoloration with small necrotic blotches.

#### 8.4.2.5 Cadmium (Cd)

Cadmium is biologically non-essential and non-beneficial constituent. Cadmium contamination imposes an adverse effect on environmental quality and constitutes a serious threat not only to plants and animals but also to human lives [Martin-Garin et al., 2002]. Maximum desirable limit of Cd in drinking water for the human beings is 0.01 ppm (WHO, 2004). The irrigation standard recommended by USEPA for Cd concentration in water is 5 ppm. CCME [2005] recommended upper safe levels of water to Cd are 0.08 ppm for livestock. The values obtained in present study from various water resources found to be higher than the maximum permissible limit of 0.01 ppm [WHO, 2004; Sindhu, 2002] as the water sources are concerned for the drinking purposes to the humans while this water is used for other purposes like irrigation to different crop plants and drinking purposes to livestock is considered to be safe. Higher level of Cd in this cold desert high altitude region may be due to the increasing pollution level by increasing the tourism and increasing activities of army vehicles in this area since the last five to ten years or the cadmium containing parent materials (rocks) available in this region. (Joradao et al., 1996) reported that Cd gets into a ground water from corrosion of galvanized pipes and fittings and to the surface water from the effluents discharged from pipe industries, in surface waters through paints, pigments, glass enamel, deterioration of the galvanized pipes etc. Cadmium is released into environment from wastewater, disperse pollution is caused by contamination from fertilizers [WHO, 2011]. The wear of studded tires has been identified as a source of Cd deposited on road surfaces.

**8.5 Conclusion**

As per the physico-chemical properties (pH, EC, TDS, turbidity, COD, salinity) of studied water resources were concerned, the water is suitable irrigation to various crop plants, drinking purposes to humans and all kind of animals. While As, Pb, and Cd are observed above the maximum permissible limit. However, our findings revealed high As, Cd and Pb level in stagnant water, river water, and irrigation water from most of the sites and therefore, may cause health hazards for human and animals. Hence long term uses of this water for drinking purposes to humans and animals should be avoided and it require suitable actions to minimize long exposure. Consequently, preventive measures are required to ameliorate any health problems due to high intake of these heavy metals in the animals. Arsenic is the most important issue in this cold desert region where it is reported in extremely higher concentrations in most of the studied areas so it is not suitable for human and animals health as well as for environment and also not suitable for irrigation purposes in long term uses.

# CHAPTER IX

# To know certain heavy metal presence and their interrelationships in forages and animals of cold desert high altitude region

## Abstract

The present study was conducted to investigate the bioavailability of heavy metals in some forage crop plants and serum samples of Changthangi sheep and goats from cold arid region. Plants are the first unit of heavy metal pollution by their potential to accumulate them when grown on contaminated soils and these plants when fed or graze by the animals then become sink of heavy metals lead to pollute the whole food chain. Therefore keeping the above point in the mind, present study was planned in the way to examined presence of heavy metals and to assess their toxicity. For the study, forages (*Medicago sativa* L. and *Triticum aestivum* L. straw) and serum samples of native Changthangi sheep and goats were collected from Leh-Ladakh: a region of harsh climatic and terrestrial conditions. Samples were analyzed for nickel, cadmium, chromium, lead and arsenic. The total mean concentration of Ni, Cd, Cr, Pb and As, were determined to be 0.500±0.04, 0.500±0.04, 12.613±0.96, 0.111±0.07, 0.096±0.02 ppm respectively in *Medicago sativa* L. samples, while in *Triticum aestivum* L. straw, these were examined to 0.457±0.04, 0.237±0.02, 33.174±4.41, 0.064±0.01 and 0.004±0.001 ppm respectively. The average concentration of Ni, Cd, Cr, Pb and As were determined to 2.021±0.124, 0.303±0.04, 10.171±0.219, 3.337±0.32, 1.731±0.377 ppm respectively in serum samples of Changthangi sheep, whereas 1.747±0.17, 0.750±0.13, 9.866±0.34, 3.322±0.54 and 0.167±0.003 ppm of Ni, Cd, Cr, Pb, As were examined respectively in Changthangi goat serum samples. Correlation analysis revealed that most of the heavy metals were observed to have correlation between forages and animals but calculated statistically non-significant ($P<0.005$; $P<0.001$). Heavy metals were examined to accumulate in plants and animals from less to higher concentration and some were found severe to toxic accumulation that may cause health risk to plants, animals and ultimately to human beings, prevailed over the studied region.

**Key words:** Heavy metals presence, forages, high altitude region, Interrelationships

## 9.1 Introduction

Bioavailability of heavy metals in plant and animals through the soil and water is the major issue of heavy metals pollution which is predicted by various scientist and environmentalists throughout the world. Further plants or the forages are essential component of natural ecosystems and agro-ecosystems represents the first section of the terrestrial food chain, due to their aptitude of toxic heavy metal accumulation and results in a threat to the living beings which consume them. The risk of heavy metal contamination in meat and blood of livestock is of great concern for both safety and human health because of the toxic nature of these metals relatively in trace concentrations [Santhi et al., 2008]. The contaminated animal feed and feeding system to the polluted environment were reportedly responsible for heavy metal contamination in meat and blood [Miranda et al., 2005]. The environmental pollutants are spread through different channels many of which finally enter into the food chain of livestock and human. There is increasing concern about environmental pollutants emanating into the livestock production systems. Heavy metal toxicity is one of the major current environment health problems and is potentially dangerous because of bioaccumulation through the food chain and this causes hazardous effects on livestock and human health. In general the hazardous effect of these toxic elements depends upon the dietary concentration of the elements, absorption of the element by the system, homeostatic control of the body for the element and also the species of the animal involved [Underwood, 1977]. Because of their very low abundance, trace elements are particularly sensitive to surrounding environmental conditions, which influence their physico-chemical speciation and their behavior in the ecosystems. The main sources of trace metals to plants are the air or soil from which metals are taken up by the root or foliage. Some trace metals are essential in plant nutrition, but plants growing in a pollute environment can accumulate trace elements at high concentrations, causing a serious risk to human health. [Alloway 1990; Vousta et al., 1996; Sharma et al., 2007]. The uptake of metal concentration by roots depends on speciation of metal and soil Characteristics and type of plant species etc. Consequently, metal mobility and plant availability are very important when assessing the effect of soil contamination on plant metal uptake, as well as translocation and toxicity or ultra structural alterations [Sresty and Madhava Rao, 1999; Chandra Sekhar et al., 2003). Atmospheric metals are deposited on plant surfaces by rain and dust. Several authors have shown a relationship between atmospheric element deposition and elevated element concentrations in plants and topsoil, especially in cities and in the vicinity of emitting factories. Widespread interest in trace metal accumulation in plant systems has emerged only over the last three decades and several research articles reported concentrations of a number of trace elements in the local crops and other plants as a consequence of anthropogenic emissions [Bernhard et al., 2004; Wong et al., 2006]. There is no any previous study in this region regarding the heavy metals pollution and their presence in the ecosystem so the present study was aimed with the objectives to investigate the presence of toxic heavy metals in soil, forages and serum sample of sheep and goats and their interrelationships in this region.

## 9.2 Material and methods

### 9.2.1 Forages sampling, processing and analysis

Lucerne or alfalfa (*Medicago sativa* L.), wheat straw, (*Triticum aestivum* L.) fodder samples were collected from studied area, fresh leaves of alfalfa (*Medicago sativa* L.) were collected on maturity of the crop plants, while the whole plant above the soil surface was collected in case of wheat straw, (*Triticum aestivum* L.). Nine sampling sites (village) were selected and fifteen small samples were collected from each sampling site and mixed and then required quantity of plant sample was taken by quartering method so the six plant samples were taken for the analysis. All the collected samples were taken in the laboratory and cleaned for the dust with flowing double distilled water and air dried. Then all the air dried plant samples were oven dried at $65^0$C for the 12 hours and then grinded in stainless steel heavy duty plant sample grinder to obtain homogeneous sample size. All the plant samples were digested on dry matter basis, plant samples were digested by using metal grade nitric acid ($HNO_3$), hydrogen peroxide ($H_2O_2$) hydrochloric acid (HCl), samples were digested on 42 blocks Automated Hot Bock digestion system (Questron Technologies Inc, Canada). Heavy metals were estimated in the above plant samples by ICP-OES (Optima 7000 DV, Perkin Elmer and United State of America).

### 9.2.2 Blood sampling, processing and analysis

Total sixty blood samples (six sites; ten samples from each sampling sites) from each native female Changthangi sheep and native female Changthangi goats were collected. About 5 ml of blood was collected from jugular vein in the vials, kept the samples at $4^0$C for overnight and then centrifuge it at 6000 rpm for 5 min, serum was collected in separate storage vials and stored at $-80^0$C. All the serum samples were digested on mass to weight basis, samples were digested by using metal grade nitric acid ($HNO_3$), perchloric acid ($HClO_4$) hydrochloric acid (HCl), samples were digested on 42 blocks Automated Hot Bock digestion system (Questron Technologies Inc, Canada). All these samples were analyzed for heavy metals by ICP-OES (Optima 7000 DV, Perkin Elmer and United State of America).

### 9.2.3 Statistical data analysis

Data generated through the study were analyzed for mean and standard error (SE) by one way ANOVA. Significance level ($P<0.05$) was generated among the different mean values by Duncan's multiple range test (DMRT) among different sampling locations. Pearson correlation coefficient ($r^2$) analysis was done in soil, plant and animals for the various essential mineral nutrients by using SPSS computer programme (SPSS, 1999).

## 9.3 Result

### 9.3.1 Level of heavy metals in fodders

The table no. 9.1 and 9.2 were shown the heavy metals concentration in various fodder samples collected from cold desert high regions. In the present study, Ni, Cd, Cr, Pb and As contents were found to 0.500±0.04, 0.464±0.03, 12.613±0.96, 0.111±0.07, 0.096±0.02, 0.497±0.02 and 17.452±1.72 ppm respectively in Lucerne (*Medicago sativa* L.) whereas the range differed from 0.024-0.993, 0.098–1.584, 0.223–35.890, 0.023–3.904, 0.001–0.423 ppm respectively in the studied samples (Table 9.1).

While on the other hand, Ni, Cd, Cr, Pb, As concentrations were reported to 0.457±0.04, 0.237±0.02, 33.174±4.41, 0.064±0.01, 0.004±0.001ppm and range varied from 0.030-0.950, 0.011-0.564, 9.070-191.0, 0.021-0.350, 0.005-0.014 ppm respectively in wheat straw (Table 9.2). The statistical analysis (one way ANOVA) revealed that, significantly ($P<0.05$) higher concetrations of Ni, Cr and As were examined at site 6 (0.825±0.06 ppm), site 6 (18.29±2.84 ppm) and at site 2 (0.312±0.01 ppm) respctively, whereas Pb and Cd were observed non significant ($P<0.05$) in lucene samples (Table 9.2).

**Table 9.1:** Heavy metal concentrations (ppm) in Lucerne (*Medicago sativa* L.) from cold desert high altitude region

| Study Sites | As | Cd | Pb | Cr | Ni |
|---|---|---|---|---|---|
| 1 | 0.132[c] ±0.02 | 0.567[a] ±0.26 | 0.027[a] ±0.00 | 6.334[a] ±0.44 | 0.117[a] ±0.08 |
| 2 | 0.312[e] ±0.01 | 0.583[a] ±0.05 | 0.031[a] ±0.00 | 14.4[abc] ±1.01 | 0.320[ac] ±0.16 |
| 3 | 0.265[de] ±0.05 | 0.500[a] ±0.04 | 0.030[a] ±0.00 | 9.075[ab] ±0.41 | 0.415[bcd] ±0.08 |
| 4 | 0.238[d] ±0.03 | 0.462[a] ±0.03 | 0.092[a] ±0.06 | 12.74[abc] ±2.17 | 0.491[cde] ±0.05 |
| 5 | 0.075[bc] ±0.02 | 0.465[a] ±0.03 | 0.029[a] ±0.00 | 11.08[abc] ±0.82 | 0.578[def] ±0.04 |
| 6 | 0.004[a] ±0.00 | 0.443[a] ±0.04 | 0.064[a] ±0.01 | 18.29[bc] ±2.84 | 0.825[g] ±0.06 |
| 7 | 0.002[a] ±0.00 | 0.377[a] ±0.03 | 0.038[a] ±0.01 | 10.07[abc] ±1.23 | 0.627[defg] ±0.07 |
| 8 | ND | 0.449[a] ±0.03 | 0.038[a] ±0.00 | 13.75[abc] ±3.81 | 0.754[fg] ±0.03 |
| 9 | ND | 0.386[a] ±0.04 | 0.038[a] ±0.00 | 12.34[abc] ±2.69 | 0.462[cd] ±0.03 |
| Mean | 0.096 ±0.02 | 0.464 ±0.03 | 0.111 ±0.07 | 12.613 ±0.96 | 0.500 ±0.04 |
| Range | 0.001 –0.42 | 0.10 –1.58 | 0.02 –3.90 | 0.22 –35.89 | 0.02 -0.99 |
| *Threshold limit | 10 | 1.0 | 50 | 2.0 | 5.0 |

Value (Mean±SE, N=6) bearing different superscripts differ significantly (P<0.05) between the row.

*Threshold limit to crop plants, [Eduardo et al., 2010 & Alvarenga, 2006]

**Table 9.2:** Heavy metals presence (ppm) in wheat straw (*Triticum aestivum* L.) from cold desert high altitude region

| Study sites | As | Cd | Pb | Cr | Ni |
|---|---|---|---|---|---|
| 1 | 0.005[b] ±0.001 | 0.452[e] ±0.03 | 0.027[a] ±0.01 | 24.590[abc] ±4.46 | 0.697[cd] ±0.08 |
| 2 | 0.004[b] ±0.002 | 0.464[e] ±0.03 | 0.031[a] ±0.01 | 16.220[ab] ±0.46 | 0.515[bc] ±0.03 |
| 3 | 0.005[b] ±0.001 | 0.310[d] ±0.02 | 0.028[a] ±0.01 | 62.784[c] ±2.90 | 0.609[bcd] ±0.08 |
| 4 | 0.007[bc] ±0.005 | 0.203[c] ±0.03 | 0.033[a] ±0.01 | 48.692[abc] ±8.36 | 0.776[d] ±0.05 |
| 5 | 0.003[ab] ±0.002 | 0.175[c] ±0.01 | 0.032[a] ±0.01 | 32.918[abc] ±1.20 | 0.071[a] ±0.01 |
| 6 | 0.010[c] ±0.001 | 0.265[d] ±0.01 | 0.200[b] ±0.07 | 11.828[a] ±0.71 | 0.475[b] ±0.11 |
| 7 | ND | 0.160[c] ±0.01 | 0.150[b] ±0.07 | 21.076[ab] ±0.87 | 0.643[bcd] ±0.04 |
| 8 | ND | 0.089[b] ±0.02 | 0.037[a] ±0.01 | 52.186[bc] ±34.71 | 0.168[a] ±0.05 |
| 9 | ND | 0.013[a] ±0.01 | 0.041[a] ±0.01 | 28.268[abc] ±0.82 | 0.156[a] ±0.001 |
| Mean | 0.004 ±0.001 | 0.237 ±0.02 | 0.064 ±0.01 | 33.174 ±4.41 | 0.457 ±0.04 |
| Range | 0.005-0.014 | 0.011-0.564 | 0.021-0.350 | 9.070-191.0 | 0.030-0.950 |
| *Threshold limit | 10 | 1.0 | 50 | 2.0 | 5.0 |

Value (mean±SE, N=6) bearing different superscripts differ significantly ($P<0.05$) between the row.

*Threshold limit to crop plants, Eduardo et al., (2010) & Alvarenga (2006)

### 9.3.2 Levels of heavy metals in serum samples of Changthangi sheep and goats

The data presented in Table 9.3 and 9.4 regarding the heavy metals in Changthangi sheep and goat serum samples. Arsenic and cadmium in serum sample of Changthangi sheep in some study sites were not detected but other metals in most of study sites were detected at various levels that may be toxic after long term exposure to the animals. Ni, Cd, Cr, Pb and As were estimated in the range of 0.040-5.352, 0.057-1.884, 0.275-20.46, 0.075-16.07 and 0.924-18.310

ppm respectively, while the total mean concentration observed to 2.021±0.124, 0.303±0.04, 10.171±0.219, 3.337±0.32 and 0.924-18.310 ppm respectively in sheep serum samples (Table 9.3).

**Table 9.3:** Heavy metal presence (ppm) in serum of native sheep (*Ovis aries* L.) from cold desert high altitude region

| Study sites | As | Cd | Pb | Cr | Ni |
|---|---|---|---|---|---|
| 1 | ND | $0.081^{ab}$ ±0.04 | $2.668^{bc}$ ±0.86 | $11.037^{cde}$ ±0.46 | $2.120^{c}$ ±0.21 |
| 2 | ND | ND | $7.752^{f}$ ±0.79 | $11.139^{cde}$ ±0.07 | $3.880^{e}$ ±0.21 |
| 3 | $0.785^{a}$ ±0.785 | $0.207^{abc}$ ±0.08 | $5.390^{de}$ ±1.13 | $9.390^{abc}$ ±0.50 | $2.713^{d}$ ±0.35 |
| 4 | ND | $0.268^{bc}$ ±0.08 | $1.085^{ab}$ ±0.26 | $9.865^{abcd}$ ±0.47 | $1.060^{ab}$ ±0.13 |
| 5 | $0.277^{a}$ ±0.277 | ND | ND | $8.320^{a}$ ±1.65 | $0.950^{a}$ ±0.19 |
| 6 | ND | $0.963^{d}$ ±0.11 | $2.596^{bc}$ ±0.38 | $8.506^{ab}$ ±0.19 | $1.124^{ab}$ ±0.15 |
| Mean | 1.731 ±0.377 | 0.303 ±0.04 | 3.337 ±0.32 | 10.171 ±0.219 | 2.021 ±0.124 |
| Range | 0.924-18.310 | 0.057-1.884 | 0.075-16.07 | 0.275-20.46 | 0.040-5.352 |

Value (Mean±SE, N=10) bearing different superscripts differ significantly (P<0.05) between the row.

Present findings revealed that, Ni, Cd, Cr, Pb and As concentrations were estimated to 1.747±0.17, 0.750±0.13, 9.866±0.34, 7.896b±0.82, 0.167±0.003 ppm while the range varied from 0.206-3.618, 0.095-2.25, 2.744-14.24, 0.987-11.95 and 0.155-0.179 ppm respectively in Changthangi goat serum samples (Table 9.4). One way ANOVA analysis between the study sites for each metal disclosed that, Cd, Pb, Cr and Ni levels were observed significantly (P<0.05) higher at study site 6 (0.963±0.11 ppm), site 2 (7.752±0.79 ppm), site 2 (11.139±0.07 ppm) and at site 2 (3.880±0.21 ppm) respectively in serum samples of native sheep (Table 9.4).

**Table 9.4:** Heavy metal presence (ppm) in serum of native Changthangi goat (*Capra hircus* L.) from cold desert high altitude region

| Study sites | As | Cd | Pb | Cr | Ni |
|---|---|---|---|---|---|
| 1 | ND | ND | $1.546^{bc}$ ±0.05 | $9.146^{a}$ ±0.12 | $1.520^{b}$ ±0.38 |
| 2 | ND | ND | $1.252^{ab}$ ±0.11 | $10.020^{ab}$ ±0.06 | $1.710^{b}$ ±0.14 |
| 3 | ND | $0.823^{ab}$ ±0.02 | ND | $10.701^{ab}$ ±1.04 | $1.583^{b}$ ±0.04 |
| 4 | ND | $1.011^{c}$ ±0.41 | $2.294^{ab}$ ±0.22 | $8.346^{a}$ ±1.85 | $0.556^{a}$ ±0.21 |
| 5 | ND | ND | $2.552^{c}$ ±0.08 | $9.286^{ab}$ ±0.14 | $1.397^{b}$ ±0.15 |
| 6 | 0.167 ±0.003 | $0.473^{a}$ ±0.01 | $7.896^{b}$ ±0.82 | $11.683^{b}$ ±0.09 | $3.565^{c}$ ±0.02 |
| Mean | 0.167 ±0.003 | 0.750 ±0.13 | 3.322 ±0.54 | 9.866 ±0.34 | 1.747 ±0.17 |
| Range | 0.155-0.179 | 0.095-2.25 | 0.987-11.95 | 2.744-14.24 | 0.206-3.618 |

Value (Mean±SE, N=10) bearing different superscripts differ significantly (P<0.05) between the row.

### 9.3.3 Correlation of heavy metals between fodders and animals

The correlation coefficient analysis ($r^2$) revealed that, levels of Ni, Cr and As in *Medicago sativa* L., were observed to be negatively correlated with the level in serum samples of Changthangi sheep while Pb and Cd were positively correlated but were statistically non significant (P<0.005, P<0.001) (Table 9.5). Similarly concentrations of Ni and Pb in *Medicago sativa* L. were negatively correlated with their levels in serum samples of Changthangi goat, whereas Cr, As and Cd levels were positively (non-significant) correlated. Further the levels of Ni, As and Cd were examined in wheat straw (*Triticum aestivum* L.) to be negatively (non-significant) correlated with their levels in serum samples of Changthangi sheep, although contents of Cr and Pb were analyzed positively correlated (non-significant). Similarly the levels of Ni and Cr in wheat straw were negatively correlated with their concentrations in Changthangi goat, whereas Pb, As and Cd positively non significantly correlated (Table 9.5).

**Table 9.5:** Correlation analysis (r) of heavy metals between forages and animals from cold desert high altitude microclimate

| Forages-Animals | Ni | Cr | Pb | As | Cd |
|---|---|---|---|---|---|
| *Medicago sativa* L. - Native sheep | -0.009 | -0.011 | 0.023 | -0.423 | 0.143 |
| *Medicago sativa* L.- Native goat | -0.288 | 0.198 | -0.056 | 0.552 | 0.198 |
| *Triticum aestivum* L. - Native sheep | -0.89 | 0.022 | 0.101 | -0.121 | -0.093 |
| *Triticum aestivum* L. - Native goat | -0.051 | -0.074 | 0.080 | 0.903 | 0.454 |

*Correlation is significant at the P<0.005 level
**Correlation is significant at the P<0.001 level

## 9.4 Discussion

### 9.4.1 Levels of heavy metals in fodders and serum samples of native sheep and goats

#### 9.4.1.1Arsenic (As)

Arsenic is a component of most plants but their biological functions has not been determined [Kabata-Pendias and Pendias, 1992]. It can be toxic to plants in leaf concentrations of 5-220 ppm on dry matter basis; the threshold limit for the plant is 10 ppm [Eduardo et al., 2010; Alvarenga, 2006]. Our present results shown that, As concentration in various forages were below the threshold limit [Eduardo et al., 2010; Alvarenga, 2006] and there is no toxicity risk in plant systems were studies. It was reported from our study that, As concentrations were also found in agriculture soil samples and even in the water samples studied since it is available in the forages grown in investigated region. As can be absorbed by the plants through the roots and foliage, toxicity may occur whenever the exchange capacity of the soil has been exceeded, regardless of actual soil As levels [NRCC, 1978b]. Toxicity in animals can be possible as a result of soil consumption and result in accumulation of As in the organs of animal, posing a possible health risk for humans if the organs or meat consumed [NRCC, 1978b]. Bioaccumulation and their toxicity of heavy metals in livestock were extensively studied by some previous workers [NRCC, 1978b; Rajaganapathy, 2009; Aycicek, 2008]. The present study reported that, As concentration in some serum samples of Changthangi goat and sheep were determined from the studied sites in cold desert high altitude microclimate. These As values are too much high than threshold limit in some sample and may cause toxicity to the studied animals prevailed here so precaution must be taken.

**9.4.1.2 Cadmium (Cd)**

Cadmium is phototoxic at a level of 5-30 ppm in leaf on dry matter basis [Kabata-Pendias and Pendias, 1992], whereas average threshold limit for the plants is 1.0 ppm [Eduardo et al., 2010; Alvarenga, 2006]. Cadmium may accumulate within edible portions of the plant to sub-toxic levels without resulting in any plant suffering [Alloway, 1990]. Cadmium can be taken up by plants through leaves or roots but soluble soil Cd is readily available [Eduardo et al., 2010; Alvarenga, 2006] and it is supposed that this is the main source of plant Cd (FAO, 1992), the actual phytotoxicity can occur on polluted soils but it is rare [Alloway, 1990] and Cd is generally not harmful to plants [FAO, 1992]. Our present results disclosed that, Cd concentration in forages in studied area observed to be below the threshold limit [Eduardo et al., 2010; Alvarenga, 2006] for the plant system so there is no problem to plant health at this study site through the cadmium accumulation. Dey et al. [1997] reported that the fodder samples in a polluted area determined the Cd concentration 1.075 ppm and further the fodders fed to the animals in industrial area of Punjab, India contained 0.50 to 10 ppm Cd [Sidhu et al., 1994]. Other workers like Parkpian et al. [2003] monitored the Cd contamination in grazing land located near a highway, grasses growing on grazing land Cd content determined to be 0.17 to 0.73 ppm. Cadmium accumulates rapidly in livestock and other animals, particularly in kidney and other organs, creating a potential hazard for human consumption [CCREM, 1995]. Accumulation of Cd in animals can cause diseases if it replaces Zn, in enzymes; symptoms of toxicity include renal degradation, emphysema, intestinal dysfunctions and anaemia [Lagerwerff, 1972]. Cd is low to be more toxic to animals if dietary calcium low [CCREM, 1995]. The total average concentration of cadmium in Changthangi sheep serum samples are observed below the maximum tolerance limit (MTL), while in Changthangi goat and sheep serum samples, in some locations Cd level monitored above the MTL [Eduardo et al., 2010; Alvarenga, 2006] and in some site it is much higher, so it is concluded that, Cd bioaccumulation is rather higher in Changthangi goat than the sheep. It seemed that Cd is coming to the animals through the drinking water from the region, because Cd was not detected in agriculture soil samples from the study areas.

#### 9.4.1.3 Chromium (Cr)

There is no evidence that the Cr is essential for plant but there are some reports of growth stimulation by $Cr^{3+}$ [McGrath and Smith, 1990]. $Cr^{3+}$ is required for removal of excess glucose in mammals [Scott, 1972] and deficiencies have been found to occur in animals and humans [NRCC, 1976] and it was reported that, $Cr^{6+}$ is toxic to both plants and animals [Kabata-Pendias and Pendias, 1992]. Phytotoxicity occurs at leaf levels of 5-30 ppm on dry matter basis and threshold limit of Cr for the crop plants is 10 ppm [Eduardo et al., 2010; Alvarenga, 2006] and there are some reports of toxicity to livestock grazing on plants high in Cr [McGrath and Smith, 1990]. Our present investigation revealed that, Cr in various forages from study area had higher accumulation that is above the threshold limit [Eduardo et al., 2010; Alvarenga, 2006] for in *Triticum aestivum* L. straw, Cr was reported above the toxic level so the severity of Cr toxicity may occur in these crop plants in this region. Cr is also observed higher in agriculture soil and other soil and sediments from our previous study, so this may be the reason of higher bioaccumulation in two crop fodders. On the other hand Cr concentration in serum samples of Changthangi goat and sheep were observed to be above the maximum tolerance limit (MTL) in Changthangi goat while in Changthangi sheep it is just about to MTL. Thus it is the matter of concern and that should be deliberated by the environmentalist and nutritionist working in this area for risk assessment projects. The higher level of Cr bioaccumulation in serum samples of sheep and goats may be due to the higher level of Cr in forages grown in this area and also higher content of Cr in soils on which these forages were grown. Bansal [2004] reported that, plants grown on sewer water irrigation area had higher accumulation of Cr than the plants grown with underground water in Aligarh, Uttar Pradesh.

#### 9.4.1.4 Lead (Pb)

Lead in non essential trace metal for plants, animals and humans, it toxic to plants at the level in leaves of 30-300 ppm on dry matter basis and threshold limit 50 ppm [Eduardo et al., 2010 & Alvarenga, 2006]. The toxicity causes dark green leaves, wilting, stunted foliage and roots [Kabata-Pendias and Pendias, 1992], although the lead can be absorbed through roots and foliage [Lagerwerff, 1972], phytotoxicity are rarely observed under field conditions. Our present study disclosed that, Pb concentration in forages from the cold desert high altitude region in India varied widely and examined to be below the threshold limit [Eduardo et al., 2010 & Alvarenga, 2006], but their bioaccumulation seemed to be found in all studied locations. Lead level was not monitored in agriculture soil but it was estimated in water resources in our previous study so this may be the reason of their Pb availability in forages growing in this region. Some earlier worker reported contamination of Pb from natural and men made resources as Rozso et al. [2003] detected Pb content in forages and roughages produced in agricultural regions and the neighboring cities, industrial plants and busy highways and reported that the Pb contamination of plants from industrial areas and nearby roads was higher than that of plants from agricultural areas. Further the Dey et al. [1997] examined the fodder samples in the polluted area and recorded total average Pb concentration in forages to 706 ppm. Mor [2005] examined the Pb content in livestock feed taken from four agricultural areas of Bursa, Turkey; among the livestock feed used green grass was found to have higher concentration of Pb than the straw. Lead is highly toxic to animals at the level of 30 ppm in diet on dry matter basis [FAO, 1992] and leads to efficiency problems in red blood cell synthesis [NRCC, 1978a]. Further the threshold limit for sheep and goats reported to be 0.5 ppm so above this level may cause severe toxicity problems. Our study reported that, Pb concentration in serum samples of Changthangi sheep and goats from this region are above the maximum tolerance limit (0.5 ppm) and somewhere it was observed above the 3 ppm in some study sites, which can pose severe health problems to the animals reared in this region. The higher level of lead accumulation in studied animals may be due to the long term uses of contaminated drinking water and forages, although Pb levels in water and forages reported to be very less in this cold arid region. The Leita et al. [1991] reported the higher level of Pb than their toxicity level in sheep organs from smelter area in Italy, as Pb in muscle 15.3 ppm and kidney 43 ppm and seven times higher content of Pb in sheep organs and tissues from industrial zone of Iraq was observed by Abbas [1992].

#### 9.4.1.5 Nickel (Ni)

Nickel is essential element for plants, because it required by hydrogenase and translocation of nitrogen and known to present in unease [Kabata-Pendias and Pendias, 1992]. It is easily translocated within the plants and accumulates in leaves and seeds [Kabata-Pendias and Pendias, 1992]. Nickel is required for animals and some instances of deficiency have been established [NRCC, 1981]. It may also essential for human health [McGrath and Smith, 1990]. Deficiency of Ni is unlikely to occur in plants or animals under natural conditions. If there is Ni requirement for plants, it is thought to be very small but met under natural conditions, whereas Ni intake levels in the animal diet are generally higher than levels shown to cause deficiencies

[McGrath and Smith, 1990]. Plants have shown the symptoms of toxicities at leaf levels of 10-100 ppm, Ni at dry matter basis and can produces chlorosis, gray-green leaves and stunted root and plant growth [Kabata-Pendias and Pendias, 1992]. Our study examined that, Ni concentrations in various forages determined below the threshold limit that is 5.0 ppm [Eduardo et al., 2010 & Alvarenga, 2006], these findings indicated that nickel is rather less in plants, unlike whatever content is available in soils and waters resources in our previous study. It seemed the transfer rate of Ni is very less from soil and waters to the plants in this region although Ni levels in soils observed much higher and within the threshold limit. It is assumed that, Ni level in soils and water resources are highly affected by prevailed harsh climatic topographical conditions in this region. On the other hand the maximum tolerance limit of Ni in feed is monitored to be 50 ppm in feeds. The levels of Ni to 40-60 ppm in organs and animal tissues is to be considered toxic for the animals so our study revealed that, lower level of Ni bioaccumulation in serum samples of Changthangi sheep and goats than their toxic concentrations.

**9.4.2 Correlation between forages and animals**

The results regarding the correlation, disclosed that, some positive and weak correlation was observed between forages and animals at this region so it is assumed that the transfer rate of studied heavy metals is rather less from the forages. These our findings substantiate with some earlier studies which also demonstrated weak or no correlations [Tejada et al., 1987; Songonzoni et al., 1997].

## 9.5 Conclusion

On the basis of results obtained in the present investigation, Cr was found above the threshold limit in *Medicago sativa* L. and wheat straw (*Triticum eastivum* L.), this is warning issue to the living beings residing in this ecosystem, because plants are the first consumer of food chain so it will lead to biomagnifications of the contaminate in the food chain including animals, humans and the environment. The level of Pb was detected in sheep and goat above the maximum tolerance limit, while Cd and Cr in some studied sites. Therefore, ameliorative measures and decontaminated drinking water access is required to reduce toxic effect of heavy metals and bioaccumulation in plant and blood of these animals at this cold desert high altitude region. Correlation findings showed that, absorption of heavy metals is highly affected by the forage and animal type at this region, because same metal in forages and animals is behaving differently unlike to their level.

# Summary/Conclusion

**To know altitudinal variations in soil physico-chemical properties of cold desert high altitude**

These results revealed that the agriculture soil at cold desert high altitude region is calcareous in nature with alkaline reaction. The relative proportion of soil fragments forming coarse grained texture in increasing order along the altitudes, constituted the sandy loam textural class. Sand fragment and SOM concentrations are positive correlated, while the pH, clay and silt contents are negatively correlated with altitude to special reference to cold desert high altitude region. Hence, our findings suggest the altitudinal variations in physico-chemical characteristics of agricultural soil at cold desert high altitude. Therefore, this study will open further scope for Researchers to look into the new soil management approaches and cultivation practices along the altitude gradients of this cold desert high altitude region.

**To know altitudinal variations in soil carbon storage and distribution patterns in cold desert high altitude region of India**

There are no published reports on soil carbon distribution along the different altitudes in cold desert high altitude region of Ladakh in India as well as in other similar regions of the world. As per this study, SOC content and stocks in agriculture soil increases while SIC content and stocks decreases with increasing the altitude. Further, SOC concentration and storage are positively correlated, whereas SIC content and stocks are negatively correlated with altitude in cold desert high altitude region of Himalayan range. However further studies on the interrelationship of environmental variables like temperature, precipitation, N availability, litter chemistry and soil carbon storage pattern in such unique harsh climatic conditions of Ladakh and other similar regions in the globe needs to be further worked out for designing the policies related to global warming as well as for recommendations regarding soil management practices for improving agricultural productivity and sustainable development of population living in these regions.

**To know essential minerals status in pasture land, road side soil and river sediment of cold arid high-altitude region**

Results of the present investigation showed that the essential minerals nutrients (total Fe, Mg, Mn, Zn, Cu, Co and B) are widely distributed and are within the normal range of soils at various studied sites at cold desert high altitude microclimate. Hence, it could be speculated that fodder/plants grown on these sites will be suitable for livestock feeding/pasture. However, various fodder/plants grow on these sites should be analyzed for minerals content and minerals supplementation, if required.

**To evaluate certain essential minerals availability in irrigation, stagnant and river (Indus) water of cold desert high altitude region**

Our study in cold arid region indicated that the various water resources having essential minerals content is lower than the optimum level that is required by the plant, animals and human beings so it is recommended that all the studied mineral elements need to be supplemented with other resources. The present study disclosed that all studied essential mineral nutrients are observed to be below the maximum permissible limit (MPL) except the Fe which was observed above the MPL as per the animal tolerance is concerned. Apart from this, water from various resources has quite good amount of all studied essential mineral nutrients so it may provide extra mineral nutrients supplement to the plant and animals other than the from feed and fodders. Further, water resources from cold desert region are considered quite sound for irrigation purposes to various crops as their mineral nutrients essentiality is concerned. However, further studies are warranted as regards its use for drinking purposes to human and animals.

**To know essential minerals status and evaluate mineral interrelationships in soil, fodders and animals of cold desert high altitude region**

The level of essential minerals in agriculture soil, fodders (Lucerne & whet straw) and sheep and goats were observed with in the normal range. Most of the essential mineral nutrients in the blood serum of local sheep and goats were investigated and results were largely differed among the sampling locations. Correlation analysis revealed that some essential mineral elements are positively and some negatively correlated in soil with plant, plant with animals and soil with animals it shows that the availability and the dynamics of mineral elements in agriculture soil is highly affected by the existing harsh climatic conditions at this region. It is assumed that complexity of studied agriculture soil is directly affecting essential minerals transfer to the plant and animals. Fodders in our study have disclosed varied level of mineral nutrients accumulation and manifestations according to the fodder types thus this indicates, the fodders grown under this microclimate have their own potential to tackle these mineral availability and accumulation problems. Therefore care must be taken during mineral mixture formulation or any feed supplement at this region for the small and large animals because fodders from this region have different level of essential minerals with different responses to the each type of mineral element.

**To know certain heavy metals presence in agricultural soils of cold arid high-altitude region**

Results revealed that, Ni and Cr concentrations in agriculture soil were measured above the threshold limit, so this may cause health risk to the living beings and ecology at this cold arid microclimate. Risk assessment of heavy metal pollution for terrestrial environments is often based on their total soil and sediment concentrations; heavy metal contamination in soil is a major concern because of their toxicity and threat to the life of plants, animals, human beings and environment.

**To know physico-chemical properties and heavy metals status in irrigation, stagnant (pond) and river (Indus) water of cold desert high altitude region**

As per the physico-chemical properties (pH, EC, TDS, turbidity, COD, salinity) of studied water resources were concerned, the water is suitable irrigation to various crop plants, drinking purposes to humans and all kind of animals. While As, Pb, and Cd are observed above the maximum permissible limit. However, our findings revealed high As, Cd and Pb level in stagnant water, river water, and irrigation water from most of the sites and therefore, may cause health hazards for human and animals. Hence long term uses of this water for drinking purposes to humans and animals should be avoided and it require suitable actions to minimize long exposure. Consequently, preventive measures are required to ameliorate any health problems due to high intake of these heavy metals in the animals. Arsenic is the most important issue in this cold desert region where it is reported in extremely higher concentrations in most of the studied areas so it is not suitable for human and animals health as well as for environment and also not suitable for irrigation purposes in long term uses.

**To know certain heavy metal presence and their interrelationships in forages and animals of cold desert high altitude region**

On the basis of results obtained in the present investigation, Cr was found above the threshold limit in Medicago sativa L. and wheat straw (Triticum eastivum L.), this is warning issue to the living beings residing in this ecosystem, because plants are the first consumer of food chain so it will lead to biomagnifications of the contaminate in the food chain including animals, humans and the environment. The level of Pb was detected in sheep and goat above the maximum tolerance limit, while Cd and Cr in some studied sites. Therefore, ameliorative measures and decontaminated drinking water access is required to reduce toxic effect of heavy metals and bioaccumulation in plant and blood of these animals at this cold desert high altitude region. Correlation findings showed that, absorption of heavy metals is highly affected by the forage and animal type at this region, because same metal in forages and animals is behaving differently unlike to their level.

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# List of Publications

**Journal Publications**

1. Jadhav SE, **Charan G**, Raj T, Bharti VK, Singh SB. 2011. Performance and blood biochemical profile of lambs fed local unconventional feed ingredients at cold and high altitude conditions of Ladakh. Indian Journal of Animal Sciences. 81(7):730-734.
2. **Charan G,** Bharti VK, Jadhav SE, Kumar S, Angchok D, Acharya S, Kumar P, Srivastava RB. 2012. Altitudinal variations in carbon storage and distribution patterns in cold desert high altitude region of India. African Journal of Agricultural Research. 7(47): 6313-6319.
3. Acharya S, **Charan G**, Singh N, Srivastava RB. 2012. Soil organic carbon sequestration of cold desert Ladakh. Range Management and Agroforestry. 33 (1):79-82.
4. Acharya S, Katiyar AK, Bharti VK, **Charan G**, Prakash B, Srivastava RB. 2012. Assessment of irrigation water quality of cold arid Ladakh region. Journal of Soil and Water conservation. 11(4):311-315.
5. **Charan G,** Bharti VK, Jadhav SE, Kumar S, Acharya S, Kumar P, Gogoi D, Srivastava. 2013. Altitudinal variations in physico-chemical characteristics of agricultural soil at cold desert high altitude. Journal of Soil Science and Plant Nutrition. 13 (2), 267-277

**Conference Publications**

1. **Charan G**, Jadhav SE, Kumar P, Bharti VK. 2011. Altitudinal variations in soil carbon distribution patterns at cold desert high altitude region of Ladakh in India. Proceedings of International conference on "Preparing Agriculture for Climate Change", February 06-08, 2011.
2. **Charan G,** Jadhav SE, Bharti VK, Acharya S, Kumar P, Gogoi D, Deshmukh PB and Srivastava RB. 2011. Altitudinal variations in soil physico-chemical properties of cold desert high altitude region of India. Proceedings of International Conference on "New Trends in Food and Health Security at High Altitude" which held at Defense Institute of High Altitude Research, Leh- Ladakh (J&K) from 23-25 Sep, 2011.

**Papers to be submitted for review**

1. **Charan G**, Bharti VK, Kumar S, Kumar P, Gogoi D, Srivastava RB. 2012. Some toxic heavy metals presence in agricultural soils of cold arid high-altitude region. Journal of Toxicology and Environment Health.

2. **Charan G**, Bharti VK, Kumar S, Kumar P, Gogoi D, Srivastava RB. 2012. Essential minerals status and their distribution patterns in cold arid high-altitude soils. Environmental Research.
3. **Charan G**, Bharti VK, Kumar S, Kumar P, Gogoi D, Srivastava RB. 2012. Certain essential minerals availability in irrigation and stagnant water of cold desert high altitude region. Nutrient Cycling in Agro Ecosystems.
4. **Charan G**, Bharti VK, Kumar S, Kumar P, Gogoi D, Srivastava RB. 2012. Evaluation of physico-chemical properties and heavy metals status in irrigation and stagnant water of cold desert high altitude region. Environmental Toxicology.
5. **Charan G**, Bharti VK, Kumar S, Kumar P, Gogoi D, Srivastava RB. 2012. Evaluation of certain essential mineral status in some forages of cold desert high altitude region. Animal Nutrition and Feed Technology.
6. **Charan G**, Bharti VK, Kumar S, Kumar P, Gogoi D, Srivastava RB. 2012. Evaluation of some toxic heavy metals presence in certain forages of cold desert high altitude region. Animal Nutrition and Feed Technology.
7. **Charan G**, Bharti VK, Kumar S, Kumar P, Gogoi D, Srivastava RB. 2012. Evaluation of essential minerals status in native sheep and goat of cold desert high altitude region. Biological Trace Element Research.
8. **Charan G**, Bharti VK, Kumar S, Kumar P, Gogoi D, Srivastava RB. 2012. Some toxic heavy metals presence in native goat and sheep of cold desert high altitude region. Journal of Toxicology and Environment Health.