TRACE ELEMENTS AND HUMAN HEALTH IN THE FOOT HILL SETTLEMENTS OF PIR PANJAL RANGE IN KASHMIR

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By

Mr. Rafiq Ahmad Hajam

Under the Joint Supervision of

Dr. G. M. Rather
(Assistant Prof.)
Co-Supervisor

Prof. Tasawoor A. Kanth
Supervisor

Department of Geography & Regional Development
(DST-FIST Sponsored and UGC-SAP Funded Department)
University of Kashmir
(NAAC Accredited Grade 'A' University)
Srinagar - 190006, Kashmir

(2015)

Department of Geography & Regional Development
(DST-FIST Sponsored & UGC-SAP Funded Department)

Certificate

Certified that the dissertation entitled "**Trace Elements and Human Health in the Foot Hill Settlements of Pir Panjal Range in Kashmir"** submitted by Mr. **Rafiq Ahmad Hajam**, in partial fulfillment for the award of Ph.D Degree in Geography and Regional Development, is based on original research work carried out by him under our joint supervision and guidance. This dissertation has not been submitted in part or in full, to any University/Institution for the award of any degree or diploma. The candidate has fulfilled all the statutory requirements for the submission of the dissertation.

Dr. G. M. Rather
Co-Supervisor

Prof. Tasawoor A. Kanth
Supervisor

Prof. Ishtiaq A. Mayer
Head of the Department

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LIST OF ABBREVIATIONS AND CODES

Districts	Codes	Altitudinal Zones (m AMSL)	Codes	Source of Water	Codes	Element	Symbol
Anantnag	ANG	Lower Foot Hills-1 (1800-2100)	LFHs-1	Tap fed by a spring	TSg	Trace Element	TE
Kulgam	KUL	Lower Foot Hills-2 (2100-2400)	LFHs-2	Tap fed by a stream	TSm	Iodine	I
Shopian	SHO	Upper Foot Hills (2400-3000)	UFHs	Stream	Sm	Copper	Cu
Pulwama	PUL			Spring	Sg	Zinc	Zn
Budgam	BUD	Others					Code
Baramullah	BAR	Essential Trace Element Deficiency Disease					ETEDD

CHAPTER-1

INTRODUCTION AND LITERATURE REVIEW

1.1. INTRODUCTION

Geomedical study of essential trace elements and human health involves analysis of cause and effect relationship of human health and geographic environment by analyzing the geo-chemical status of soil, water, food items and air, assessing the dependence of people on local food items and their nutrient content, the prevalence of food preparation and cooking methodologies, incidence and prevalence of related disorders in the community, and mapping and modeling the spatial distribution and correlation of the human health with the physico-chemical and socio-economic factors. Both the physico-chemical (as nutrients in soil, water or food) and socio-economic (as income levels, type of diet, cooking styles, and the like) determinants have a close relationship with the human health.

The essential trace elements primarily occur in rocks and are transferred to the soil and water systems through a complex network of processes wherefrom their exposure to humans is increased. It is from here that these elements enter into the food chain and reach the human body leading to their imprints in terms of different states of health. Trace elements reach into the human body through drinking water, food intake, or air. The concentration of trace elements in soil, water or food items is mainly determined by the geological conditions of the area. Both natural processes such as weathering, erosion, pedogenesis and volcanism and human activities such as mining and smelting are responsible for the redistribution of the trace elements in the soil, and water and organic environments through a network of pathways called as biogeochemical cycles. Food chains play an important role in the transfer of trace elements from soils and waters to plants and animals/humans and then to human beings and finally back to the geo-physical environment.

The amount of a particular element that reaches a human body from the food chain depends upon a series of intervening human activities or factors such as dependence on local/non-local foods, amount of food taken, type of food taken, use of boiled or non-boiled water, methods of cooking, type of salt used, income level of the people and the like. These socio-economic factors directly and indirectly limit the quantity of trace elements in the food intake. These factors act as links between the human body and the food chains and determine the deficiency or toxicity of a particular element in the human body.

The essential trace elements have a crucial and important role in the survival of life and maintenance of good health. Human health is determined and conditioned to a great extent by the essential trace elements. So, whenever there is deficiency or toxicity of these elements in the human body, there occurs a series of health ailments. But, the deficiency of these elements in human body occurs only when there is deficiency of them in their diet because diet is the main source of these elements for humans. Diets become nutrient deficient when there is deficiency of the nutrients in the soil and water. Also, they are rendered deficient due to the socio-economic factors like food preparation and cooking methods and others.

It was in the first part of the 20th century that scientists could detect small amounts of mineral elements in living organisms which are now called as trace elements. The trace elements found in living organisms may be essential, i.e., important for performing function necessary for life, or they may be non-essential in their original specific state but can be beneficial to health through pharmacological action. All trace elements even essential ones are poisonous for health in their imbalanced state i.e., in concentrations more or less than required quantity.

In the 1960s and 1970s, the standard to define a nutrient as essential was liberalized for mineral elements that could not be fed in amounts low enough to cause death or interrupt the life cycle (interfere with growth, development or maturation). Thus, an essential element was defined as one whose dietary deficiency consistently and adversely changed a biological function from optimal, and this change was preventable or reversible by physiological amounts of the element. Later on, this definition of essentiality became less acceptable when a large number of elements were suggested to be essential based on small changes in physiological or biochemical variables. Many of these changes were questioned as to whether they were necessarily the result of a suboptimal function, and sometimes were suggested to be the consequence of a pharmacological or toxic action in the body, including an effect on intestinal microorganisms. As a result, majority of scientists now define an element an essential only if it performs a defined biochemical function. However, some scientists still rely on the older definition. So, it is clear there is no universally accepted list of trace elements, though WHO has listed six elements as essential i.e., Cu, Zn, I, Mo, Se and Cr (WHO, 1996).

Cu, Zn, I, Mo, Se and Cr are uncontroversial essential trace elements. Specific biochemical functions have been defined for all of them. Below are given some important bases through which one can identify that an element is essential.

1. A dietary deficiency consistently results in modified biological function, body structure, or tissue composition that is preventable or reversible by an intake of an apparent physiological amount of the element in question.

2. The element fills the need at physiological concentrations for a known in vivo biochemical action to proceed in vitro.

3. The element is component of known biologically important molecules in some life forms.

4. The element has an essential function in lower forms of life.

When an essential trace element is absent or too low for adequate activity of an essential body function for long time, death takes place. As the intake of the essential trace element increases, the following events/phenomena take place: i) the organism/human being survives but with suboptimal health and well-being, ii) as intake reaches to normal content in which optimal health and well-being are maintained. This normal range is quite large because of powerful homeostatic mechanisms and iii) a decline in health and well-being, and finally death, as regulatory mechanisms are overcome by increasing intakes that become toxic.

The homeostatic regulatory mechanisms involve the processes of absorption, storage and excretion. The relative importance of these processes varies among the trace elements. The absorption of cationic trace elements such as copper, zinc, etc. is controlled by the gastrointestinal tract (GIT). If the amount of the element is low in the body, amount of absorption from GIT is increased and vice versa. But, the anionic trace elements such as selenium and iodine are usually freely absorbed from the GIT. Excretion through the urine, bile, sweat and breath is, therefore, the major mechanism for controlling the amount of these trace elements in the organism. Some of these elements are prevented from causing adverse reactions when present in high quantities by being stored at inactive sites (e.g., copper as metallothionein; iron as ferritin). Release of a trace element from storage forms also can be important in preventing deficiency.

Generally, simple essential trace element deficiencies are uncommon due to powerful homeostatic mechanisms. However, there are certain situations which reflect the nutritional significance of these elements. These are i) inborn metabolic abnormality which led to abnormal absorption, retention and excretion, ii) alteration in metabolism and/or biochemistry as a secondary result of malnutrition, disease, injury, or stress, iii) marginal deficiencies (slight deviation from an optimal intake of an essential nutrient) induced by various dietary manipulations or by direct or indirect interaction with another nutrient or drug, and iv) the enhanced requirement for a trace element caused by sudden or severe change in the system requiring that element. It can be summed up that the insufficient intake of a specific trace element would become obvious only when the body is stressed in some way that enhances the need or interferes with the utilization of that element. It can be presented through formula as:

Pathological Effects = Stress × Organic Vulnerability (Tapp and Natelson, 1988 cited in Nielsen, 2008).

The above mentioned formula seems quite valid for trace element nutrition. It can be said that pathological effects are not likely to be seen if a trace element deficiency (organic vulnerability) is not coupled by some significant stress. Likewise, the pathological effects are not large if stress is not accompanied by an organic vulnerability.

1.2. SIGNIFICANCE OF THE STUDY

The essential trace elements are very important for the human health. Since, they primarily occur in rocks and are transferred to the soil and water systems through a complex web of processes wherefrom their exposure to humans is increased. It is from here that these elements enter into the food chain and reach the human body leading to their imprints in terms of different states of health. These elements are increasingly been recognized as vital to human health. They are components of haemoglobin, DNA, RNA, and various enzymes (Warren, 1991). These elements play an important role in the synthesis of both proteins and nucleic acids. Each trace element has a standard requirement adequate for human health recommended by W. H.O (Fishbein, 1986). Since they are very essential for human beings, they may cause different health problems when their intake is less or more than required amounts. All essential trace elements either in excess states or in deficit states are known to create serious health problems particularly in the areas where these are regionally deficit (Hunter & Akhtar, 1991) or surplus. Diseases due to imbalance of trace elements for iodine, copper, zinc, selenium, molybdenum, manganese, iron, calcium, arsenic, and cadmium and radon are well established.

Trace elements play a number of functions in the living organisms/human beings. Their importance and role is given under five major categories of functions which are as (Nielsen, 2008):

1. Some elements occur in close association with enzymes forming metallo-enzymes and are so integral parts of catalytic centers at which the biochemical reactions necessary for life occur.

2. Some elements donate or accept electrons in reactions of reduction or oxidation. In addition to the generation and utilization of metabolic energy, redox reactions frequently involve the chemical transformation of molecules.

3. Some elements particularly iron, bind, transport and release oxygen within living organisms.

4. Some elements have structural roles, imparting stability and three-dimensional structure to important biological molecules.

5. Some elements have regulatory roles. They control important biological processes through such actions as inhibiting enzymatic reactions, facilitating the

binding of molecules to receptor sites on cell membranes, altering the structure or ionic nature of membranes to prevent or allow specific molecules or ions to enter a cell, and inducting genes to express themselves, resulting in the formation of proteins involved in life processes.

In developing countries, the deficiency of essential trace elements in the soils, waters and diet is widespread resulting in diverse health and social problems, such as mental retardations, impairments of the immune system, degenerative disorders, thyroid disorders and overall poor health. According to UNICEF (2002), ‘IDDs remain a major public health problem….Globally an estimated 740 million people are affected by goiter and nearly more than 2 billion are estimated to be at risk of IDDs’. Zinc deficiency is recognized as a major problem of human nutrition world-wide. It has been estimated to affect up to one-third of the world's population and inadequate dietary intake of bioavailable forms of Zn is considered the most frequent cause of Zn deficiency (Roohani, 2012). Zinc deficiency, for example, represents a major cause of child death in the world and is a widespread global issue (Cakmak, 2009).

Endemicity of many chronic or mild disorders such as goiter, dental fluorisis, cancers, skin disorders, etc. is quite prevalent across the spatial extent of India spanning from Kerala in South to Kashmir valley in North and Rajasthan in West to West Bengal in East because of the variable concentrations of certain trace elements such as arsenic, fluoride, iodine, cerium, etc. (Mukhopadhyay, 2005). Mayer while working out the goiter incidence in Kashmir Valley during 2004-2005 found that Anantnag district has the highest incidence of goiter and he suggested that nature of bedrock and soils is responsible for the variable goiter incidence in the valley.

Therefore, the present research work was focused to investigate, ‘Trace elements and human health in the foot hill settlements of Pir Panjal Range in Kashmir’. It was, first, carried out to analyze the essential trace element status in the soil and water systems of foot hill settlements of Pir Panjal range in Kashmir and dependence of people on local food items and relationship of the two and second, their cumulative effect on human health that would serve a base for the subsequent developments in the field and to the concerned management bodies.

1.3. OBJECTIVES

1) To determine the concentration of essential trace elements in the soils. From the soils, these elements enter into the food chain and reach to the human body.

2) To determine the concentration of essential trace elements in the drinking water sources. The content of these elements in the drinking waters directly reaches to the human body by using the water in drinking and cooking purposes.

3) To assess the dependence of people on the local food products. It is because the local food products constitute the main diet of the people and it is the main source of essential trace elements for human body.

4) To analyze the impact of essential trace element deficiencies and toxicities in the soils and dinking waters (and hence local foods) on the health of the people. The prevalence of essential trace element deficiency diseases is to be appreciated in relation to the concentration of essential trace elements in the soil and drinking waters and socio-economic character of the people of the area.

5) To suggest a suitable planning strategy. A suitable planning strategy is to be suggested to reduce the magnitude of the prevalence of essential trace element deficiency and toxicity diseases in the area.

1.4. REVIEW OF LITERATURE

Though analysis of trace element-human health relationship is a recent geochemical approach in medical geography, it was probably since mid-1950s that medical geographers, medical scientists, geochemists, and medical geologists paid a good attention to this aspect and a good amount of literature, though scattered, is available in the form of books and research articles published across the world and on internet. Some notable contributions are as follows:

Warren and Delavault (1949-1960) while working on the concentration of heavy metals (Cu, Pb, Zn) in certain plants of Montreal, Canada, concluded that metal uptake by the plants is related to underlying bedrocks and the soils developed from them. This means that the soil chemical composition is mostly the reflection of the bedrock and the same is reflected in plant tissues.

Cannon (1964) pointed out that heavy metal concentration above normal values in human body is known to disturb the rate of body growth, mental development and degree of sensitivities in the sufferers.

The investigation of copper concentration in different parts of human body led Blanke (1971, cited in Nergus, 2002) to conclude that about 50% of it concentrates in muscular tissues such as liver and brain thereafter increasing its urinary excretion.

Akhtar (1978) carried out goiter zonation in Kumaon region. He dealt in detail with the causes of goiter in the Kumaon region in special and Himalayan belt in general. The main cause of goiter is iodine deficiency in human body developed due to ingestion of iodine deficient food. Calcareous bed rock areas and glaciated areas have been identified more prone to goiter incidence for these areas are robbed of iodine through the translocation and leaching processes. Cropping patterns also contribute their part in removing the iodine from the soil.

Pyle (1979) highlighted that three kinds of environmental elements may place human tissues in jeopardy: inorganic, organic and socio-cultural. May intended inorganic stimuli to include such natural environmental aspects as heat, humidity, wind, luminosity, and mineral trace elements in soils and water. Pyle has also focused on that there exists a good relationship among such natural features as bedrock type, water pollution, animal food, soil properties, (human health), plants and man's ingestion of food and water. He pointed out that more meaningful associations can be drawn in rural areas. Moreover, he mentions that recently Warren examined the same metals and compared British and Canadian examples (diseases) to common garden vegetables such as lettuce, cabbage, potatoes, beans, carrots and beets.

The concentration of trace elements decreases progressively in leaves, twigs, cones, wood, roots and bark. He also highlighted that different species of plants take up different amounts of inorganic materials from the soil. The inorganic minerals are absorbed through leaves also.The concentration of trace elements in the soils varies from one to the other type e.g., the chernozems, some saline soils, and vertisols are richest in copper content (average value is 20 ppm) for it depends on parent rock, humus content, pH, etc. (Pinta and Aubert, 1980). The clay crystals and organic matter bind up the metal ions in the soils. pH increases the mobility of the metals in the soils.

Lag (1983, cited in Nergus, 2002) discussed the scope of Geo-Medicine in Norway and established a relationship in the transfer of elements from soil to plants and animals and finally to human beings living under varying geographical controls which further complicates the mobility of the elements. He worked on Zn, Cd and Pb concentrations in soil and plants of Roros and King-berga area of Norway and found that sheep eating grasses grown on high copper content soil died due to copper poisoning.

Paleozoic sedimentaries, Triassic Limestone, Karewas and alluvium are the predominant geological formations of the Pir Panjal with lime stones, volcanics, shales, sandstones, and unconsolidated sediments as the dominant lithologies (Wadia, 1981). The higher altitude regions (>3000 m AMSL) are mostly occupied by the Panjal Traps and the Triassic Limestone. The valley is filled up with a great thickness (>2000 m) of fluvio-lacustrine sediments of Quarternary age belonging to the Karewa Group and river deposited alluvium of recent age. The bedrock is either Triassic Limestone or Panjal Traps.

The deficiency of copper in humans may result in many diseases such as: retarded growth, hair and weight loss, disorders of nervous system, osteoporosis and Menke's syndrome. While as an excess of Cu causes Wilson's disease, mostly ending in death (Aaseth and Norseth, 1986).

GIT cancers such as of esophagus, stomach, particularly in women and the subsequent mortality may be related to the local geology or soil composition as found in Britain, North Wales, and other parts of the world (Learmonth, 1988). Again, he proposes that a range of factors such as the trace elements in soil and water and hereditary predisposition are associated with the diseases such as cancers, cardiovascular disorders, diabetes, goiter, etc. in different parts of the world.

Misra and Mani (1990) found that lead contamination of foods leads to chronic illness characterized by severe anaemia and changes in kidneys arteries. Lead enters into human body by inhalation and ingestion. Lead poisoning can cause severe mental retardation or death and persons who consume fresh garden salads are more affected than others because leafy vegetables absorb more lead (Misra and Srivastava, 1990).

The North-eastern India especially West Bengal is notorious for arsenic toxicity or contamination. Misra and Shukla (1990) found that arsenic poisoning causes a number of health disorders in humans in almost all amounts if taken over a longer duration of time.

The deficiencies of micronutrients in soils are commonly related to low contents of these elements in the parent rocks or transported parent material and toxic quantities are commonly related to abnormally large amounts in the soil forming rocks and minerals (Brady, 1990).

While analyzing the concentration of trace elements in the different spheres of earth, Warren (1991) pointed out that trace elements are more likely to be more concentrated and much more unevenly distributed in the earth's crust than they are in the oceans. Anomalous concentrations of trace elements are much commoner in the earth's crust than they are in the oceans and atmosphere.

Hunter and Akhtar (1991) worked out that while naturally occurring contaminants may be harmful to man, health may be adversely affected where there is absence or deficiency of essential trace elements such as iodine, copper or zinc. So, the human health is conditioned by the dietary intake of essential trace elements as well.

Lag (1992, cited in Nergus, 2002) investigated that mankind is affected in many ways by fertilizers, lime discharges and chemicals. The term anthropogenic soil is used when the original characteristics of the soil have nearly changed. He suggested that air, water and soil often cause serious problems of geo-medical character.

Shukla and Srivastava (1992) made analysis of rice, roots and soil and found that plants selectively absorbed the heavy metals from the polluted soil and ingestion of the contaminated heavy metal rich rice caused osteomalacia.

Man's physical and mental health depends on the genetic and environmental factors (Agnihotri, 1995). The components of natural environment such as the land, the water, the flora and the fauna make certain places more suitable for human habitation and healthy living than others. Again, the group of inorganic factors influencing human health consists of geology, relief, climate, hydrology, and edaphic resources. Quality and quantity of available water for drinking purpose determines the health status of the people.

Alloway (1995) has put forth that trace elements occur as trace constituents in the minerals of the rocks among them sedimentary rocks have monopoly on the surface of earth. It has been found that black (bituminous) shales contain high concentrations of several metals and metalloids, including As, Ag, Cu, Cd, Pb, Mo, U, V, and Zn.

Needleman, *et al.* (1996) have pointed out that more recently, it has been suggested that lead in urban areas can cause social problems such as attention deficit, delinquency and aggressive behavior. Newsome *et al.* (1997) analyzed the lead contamination in soils and found that imbalances in its concentration in soils, air, water or food have adverse health effects on humans. Although adults are at risk from high lead levels, fetuses, infants, children, under the age of seven, and expectant mothers are most at risk.

Iodine deficiency has been identified all over the world. It is a significant health problem in 130 countries and affects 740 million people. Jammu and Kashmir is a state particularly affected by iodine deficiency. An extensive survey on school children spanning three years (1993-1995) revealed that 45.2% of children were having thyroid enlargement and quantification of urinary iodine excretion demonstrated iodine deficiency. In some highland areas of the Valley, goitre prevalence was as high as 70% to 77% (Zargar, *et al.*, 1997).

Akhtar (1997) related high prevalence and incidence of cancers such as cancers of colon, leukemia, stomach, larynx, thyroid, etc. in Kerala to trace elements (radioactive) such as ilmenite, cerium, uranium, zircon, goitrogen etc. occurring in soils and locally produced and consumed food products. He also studied geographical distribution of Cancer in India. He concluded that each region has typical type of cancer, related to the region's physical and cultural characteristics. The occurrence and distribution of cancer in India is deep rooted cultural practices, socio-economic standards and the diet intake. Physical environment plays its role in altering the trace elements in the soil and water.

Haque (1998, cited in Nergus, 2002) reported that cardiovascular mortality rates are much higher in those countries where the rocks are geologically very old. This may be due to high heavy metal content in the rocks.

Keller (1999) has mentioned that lead poisoning is an example of geologic, cultural, political and economic influences on patterns of disease. He points out that lead poisoning causes anemia, mental retardation and palsy. It occurs in human bodies in a number of ways and sources. Mining and smelting are the primary activities responsible for it.

Keller (1999) while making study in American cities highlighted that observations over many years have suggested that some regional and local variations in human chronic diseases such as cancer and heart disease are related to the local geo-environmental conditions. Further he proposed that radioactive Radon-222 present in the soils and ground water is the probable cause of the lung cancer.

Investigations in the area of silicon toxicity are almost invariably associated with the silicosis problem (Nath, 2000). This disease occurs in certain classes of miners as a result of continued inhalation of silica particles into the lungs. He also points out that epidemiological studies in the USA have shown negative correlations between lithium in drinking water and mortality, especially from heart disease, and admission rates to mental hospitals. Nath (2000) further points out that ingestion of large amounts of fluoride (5-40 mg d^{-1}) in drinking water produces severe forms of skeletal deformity. These include kyphosis, fixed spine, and other joint deformities, and the dramatic skeletal manifestations of the disease genu valgum.

A varied number of factors can greatly influence the micronutrients nutriture and their identification and recognition can enhance our understanding of effects of trace elements on health (Bogden, 2000). Moreover, he mentions that these factors include interactions between micronutrients, dose-response effects, oxidation state, binding to enzymes, and other macromolecules, chelation, immutability and bioavailability (also absorption and excretion behavior).

While analyzing the dose-effect relationships, Markert *et al.* (2000) have pointed out that a positive relationship exists between dose of a pollutant and the harmful effect it causes on the organism i.e., more of substance X is taken in, the greater is effect Y. When the concentration is increased further, a stage reaches when the system becomes saturated. Copper, manganese, selenium, cobalt and zinc, e.g., are essential trace elements whose absence inevitably causes several deficiency diseases or loss of proper functioning. On the other hand, large doses are cytotoxic or cause cancer.

Ursinyova and Hladikova (2000) analyzed the concentration of lead in many countries of Central Europe. They pointed out that lead found in the earth's crust enters into physical (soil, water, atmosphere) and organic systems through physic-anthropogenic processes and adversely affects many organ systems in the human body (also plants), especially central nervous system of children, manifesting itself as an impairment of cognitive functions.

Nergus (2002) has highlighted in her research work "Problems of health and environmental geochemistry" that in addition to development of various diseases, imbalance in concentration of heavy metals in the human body affects the general health, growth and social behavior of human beings. She also pointed out that imbalance in trace metals in human body may affect daily life activities to a great extent. Such conditions may lead to various types of tumors, heart diseases and psychic conditions that damage/retard memory and intellectual abilities of human beings.

Jeelani (2004) studied chemical characteristics of natural springs of Anantnag. He pointed out that subsurface lithology is responsible for the different concentrations of heavy metals in water. The high concentrations of iron and chromium are because of lithology. But the high and variable concentration of zinc ($Zn=2\text{-}38^{-6}$ mol/kg), although within the drinking water quality standards is related to the fertilizer application in the area, as zinc sulphide is common component of the fertilizers used for rice cultivation.

Hazra (2004) while analyzing the arsenic problems in West Bengal found that arsenic poisoning is endemic to West Bengal and its sporadic distribution is perhaps related to the geology and geomorphology of the area.

Zinc is an essential microelement for biological systems of plants, animals, and humans, taking part in many physiological reactions. It behaves like a traffic policeman, directing and controlling the flow of processes in the organism and regulating enzyme systems and cells (Komatina, 2004).

Jain (2005) while analyzing the ground water quality of District Dehradun found that the trace elements in ground water except iron and nickel, which are present in appreciable concentration, are below the prescribed maximum permissible limits. The concentration of manganese, copper, chromium, lead, cadmium, and zinc have been found within the permissible limits.

Iodine was first element recognized to be essential to human beings. The deprivation of the element in the body causes a series of iodine deficiency disorders, the most common of which is endemic goiter (Fuge, 2005). Highlighting the concentration of iodine in different rocks, sedimentaries contain greater concentration with clay-rich or argillaceous rocks more enriched than others. The iodine moves like other elements in a cyclic manner in the earth system.

Selenium, a naturally occurring metalloid is essential for human and animal health in trace amounts but is harmful in excess (Fordyce, 2005). Since diet is the most important source of selenium in humans, understanding the mobility and behavior of environmental selenium is the key to the assessment of selenium related health risks.

Mayer (2007) highlights that where the bedrock structures are made up of limestone, the areas are prone to be goitrous. Water flowing through rocks contains large quantities of lime and makes thyroid gland to function more than its normal activity and thus contribute to the goiter incidence. The disease can also be associated with granites and quartzite. Mayer while working out the goiter incidence in Kashmir Valley during 2004-2005 found that Anantnag district has the highest incidence of goiter. He suggested that nature of bedrock and soils is responsible for the variable goiter incidence in the valley.

Kabata-Pendias and Mukherjee (2007) described that soil is the main source of trace elements for the plants both as micronutrients and as pollutants. It is also a direct source of these to humans due to soil ingestion affected by ‘pica-soil’, geophagia, dust inhalation, and absorption through skin. They, moreover, mention that soils contain trace elements of various origins: a) lithogenic, b) pedogenic and c) anthropogenic.

Galan, *et al*. (2008) uses the term “geochemical baseline” to contextualize the trace element concentrations in different geologic and geographic environments, officially introduced in 1993 in the context of the International Geological Correlation Program (IGCP Project 360), Global Geochemical Baselines. It includes the geogenic natural concentrations (natural background) and the diffuse anthropogenic contribution in the soils. Geochemical baseline concentrations depend not only on the dominant soil forming factors (parent rock, climate, topography, biota and time) but also on sample material, grain size and extraction method. The soils developed on crystalline rocks of the southern Iberian Massif are characterized by geochemical baselines with high concentrations of potentially toxic trace elements. Parent rock lithology and mineralisation seem to be the main factors influencing the abundance and distribution of trace elements. Significant enrichments of Co, Cr and Ni are observed in soils derived from basic and ultrabasic rock throughout the survey area. The highest concentrations of the remaining elements are found in soils derived from acid igneous rocks of the South Portuguese Zone, SPZ (median values: 34 mg kg^{-1} of As, 56 mg

kg^{-1} of Pb and 57 mg kg^{-1} of Cu) and those developed on carbonate rocks of the Ossa-Morena Zone, OMZ (median values: 28 mg kg^{-1} of As, 44 mg kg^{-1} of Pb and 83 mg kg^{-1} of Zn).

Marmiroli and Maestri (2008) have pointed out that there is correlation between endemic diseases and geological features and so the concentration of trace metals/elements in the soil and water affects the local population through availability in diet. Selenium, cadmium, zinc, fluoride, etc. are many trace metals for which geological correlates are stronger.

Environmental exposure to arsenic has serious consequences for human health with common chronic effects including skin disorders and internal cancers (West and Coombs, 2009). Highlighting that both aquatic and terrestrial invertebrate can be used as biomarker species, they, pointed out that there was a good correlation between the effects on the worms and concentrations of arsenic in soil.

Appleton (2009) has worked out that mercury is a potent toxin that can have adverse effects on physiological and neurological processes of which the degeneration of the central nervous system is the most pronounced. While working on mercury menace, he, found that mercury and cyanide pollution caused by Diwalwal mines in Philippines has produced 50 percent decline in rice yields from 1980s to 1990s, together with unexplained skin disease in the local population and the death of a significant number of oxen.

Geology can affect plant, animal and human health in the physical sense such as volcanoes, etc. whereas elements such as arsenic and mercury are toxic at high doses (Fordyce, 2009). Geological factors such as rock types determine the chemical composition of essential nutrients and toxic elements in the soils and waters that form the basis of plant-animal-human food chain.

Fortey, *et al*. (2009) by applying scanning electron microscopic (SEM) technique found that lead, cadmium and other toxic heavy metals have a potential to cause health hazards in humans such as occurred in the American cities near Brownfield sites especially those in proximity to housing or earmarked for land reclamation.

The soils of India suffer deficiencies in micronutrients such as Zn, Fe, Cu, Mn, B, Mo and S by 48%, 12%, 4%, 5%, 33%, 13% and 41% respectively (Singh, 2009). About half of the Indian soils are categorized as zinc deficient. Zn deficiency is further expected to increase from 49% to 63% by the year 2025 as most of the marginal soils are being brought under cultivation. Since rice is the staple crop of the country and is highly sensitive to Zn deficiency, it contains low Zn content which in turn may lead to the impairment in growth and immune functions leading to infectious illness and the risk of mortality especially in young children. Most of the Indian soils are adequate in Mo but its deficiency was found more in acidic, sandy and leached soils. Its deficiency is reported more in eastern high rainfall zone. Mo is found in high concentration in grain legumes. Mo toxicity is reported in animals and humans in some parts of Punjab which affects the copper utilization in the body due to Mo-Cu interaction.

Trace elements or heavy metals which are present in the rocks of the earth's crust are scavenged from them by leaching (Jeelani, 2010). Jeelani while working on the water quality of the Anantnag springs has found the concentration of certain trace elements such as iron and chromium higher than permissible limits that may had been scavenged and leached from the hosted carbonate rocks, basalts and sediments.

Jeelani (2010) while conducting the chemical analysis of Anantnag spring waters found that all the major ions such as magnesium, calcium, sodium, potassium, chloride, etc. and heavy metals such as Pb, Zn, Cd, Cu, and Mn are below the WHO permissible limits of drinking water quality standards with the exception of Fe, and Cr. The respective concentrations of Pb, Zn, Cu, Cd, Mn, Fe and Cr are 0.002-0.02 ppm, 0.1-2.5 ppm, 0.01-0.1 ppm, nd-0.002 ppm, 0-0.1ppm, 0.08-0.51 ppm and 0.04-0.06 ppm.

The trace elements occur naturally in soils, some are essential micronutrients for plants and animals, and are thus important for human health and food production (Hooda, 2010). At elevated levels, however, they become potentially toxic. Their introduction into food chains through human activities poses a range of ecological and health problems.

Khan *et al*. (2010) highlighted that use of trace element ions in modern day industries and agricultural sector has increased tremendously and has deteriorated groundwater quality. They found that some groundwater samples had marginally high concentration of Mn, Fe, Pb, and Cr, whereas, concentration of Al and Sr in water samples is very high as per W.H.O. standard for potable water. These high concentrations of metal ions in groundwater was probably due to unsafe discharge of effluent from sugar mill, pulp and paper, cooperative distilleries, municipal wastewater, fertilizers and other industries.

According to a recent research conducted in 2013 on school children of Kulgam district of Kashmir valley, it was found that 18.9% of school children suffer from Total Goiter Rate (TGR). The percentage prevalence was found relatively greater in male students than in female students. Out of total, 21.2% were boys and 16.7% were girls (Khan, *et al*., 2014).

Hajam *et al.* (2015) while conducting a study on the Zinc-Copper deficiency diseases in the foot hill settlements of Pir Panjal range in Anantnag district of Kashmir valley revealed that the deficiency of zinc and copper in the soils and drinking waters (and hence food) is responsible for the prevalence of these diseases in the area. It has also been pointed out that the socio-economic character of the people played an important role in the determination of the prevalence of these diseases.

CHAPTER-2

STUDY AREA

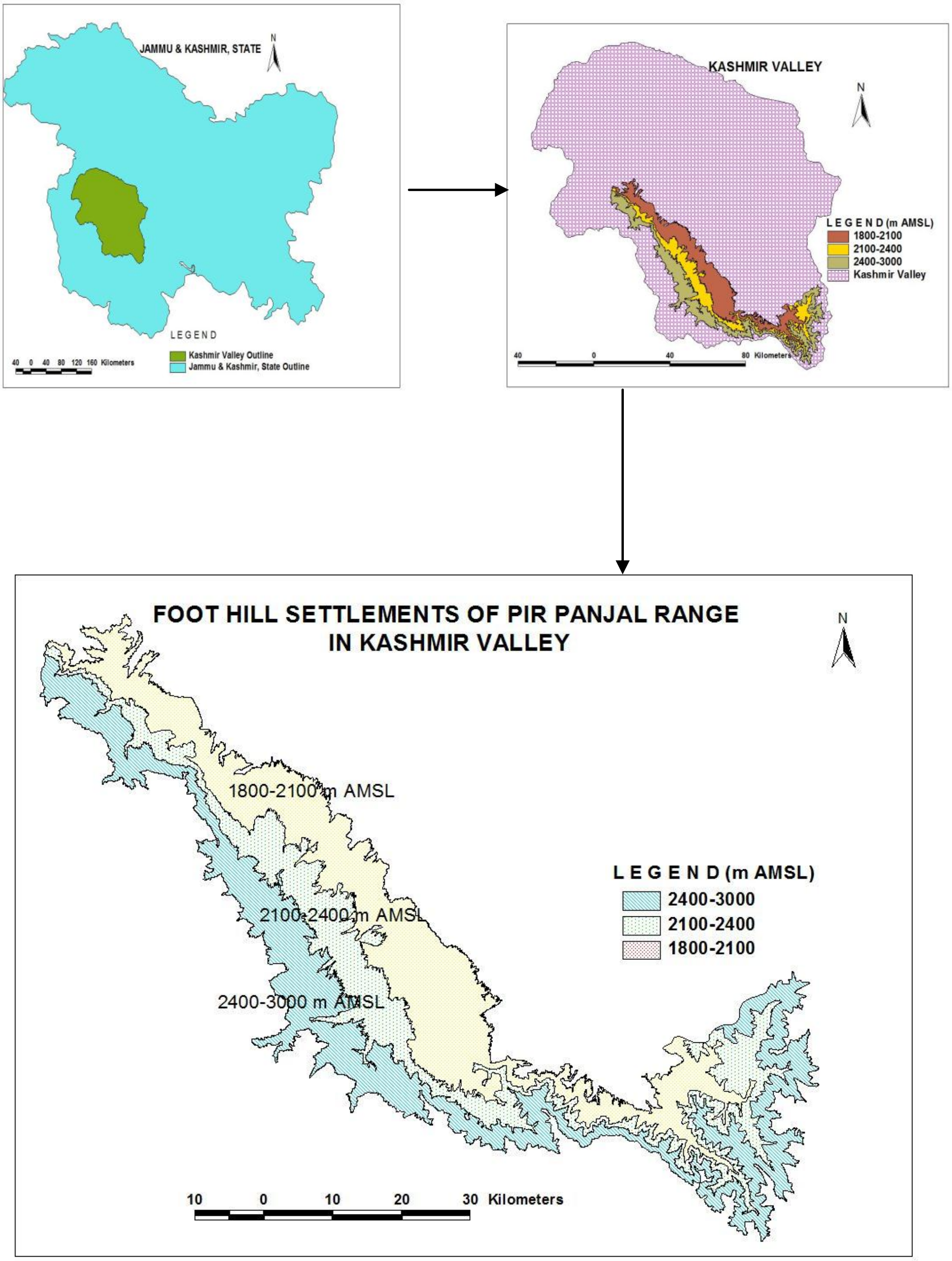
2.1. PHYSICAL SETTING

2.1.1. Location

The study area lies spatially between the geo-coordinates of $33^o23'$ 04.62″ to $34^o12'$ 27.18″ N latitude and $74^o15'$ 43.32″- 75^0 29′ 01.32″ E longitude with a total area of 2, 255.36 sq. km. comprising 18.24 percent area of the total Kashmir valley (Map 2.1). Foot hills of Pir Panjal range (westernmost mountain range of middle Himalayas separating Kashmir division from the Jammu division) in Kashmir are defined as the gently sloping Karewas, with a slope of 10^o-30^o, facing the Kashmir valley, forming an important sub-physiographic division of the region. The area is just an arc shaped longitudinal section of the Pir Panjal range in Kashmir, juxtaposed between the plain area and the mountainous area averagely at an elevation of 1,800-3,000 meters above the mean sea level. The foothills, the transitional, gentler, fertile and resource rich tracts, are studded with numerous springs which serve as primary water resource for the people living in these areas. Most of the springs of Kashmir Valley are concentrated in the foot hill zone of the Pir Panjal range (Raza, *et al*., 1978). The famous springs and tourist resorts of Kokernag, Verinag, Gulmarg, and the like are situated in the area. The area spans over six districts of the Kashmir valley covering major portions of Anantnag, Budgam and Shopian, followed by Baramulla, Kulgam, and Pulwama. The foot hills occupy 547.07 sq. km. (24.25%) area in Anantnag, 496.47 sq. km. (22.02%) in Budgam, 462.92 sq. km. (20.52%) in Shopian, 388.17 sq. km. (17.21%) in Kulgam, 298.84 sq. km. (13.25%) in Baramullah and 61.89 sq. km. (2.74%) in Pulwama districts.

2.1.2. Geomorphology

Foot hills are the intervening tracts between the plains and the mountains. The foot hills of Pir Panjal range in Kashmir are Karewa-studded, gently sloping features with a slope ranging from 10^0-30^0 interspersed by protrusions of small hills of an average altitude of 2,500 meters above mean sea level. Covering the valley of Kashmir on its south-western side from Anantnag up to Baramulla, foot hills are located at an average altitude of 1,800-3,000 meters above mean sea level. Being an inherent component of the Pir Panjal range, the foot hills have undergone the intertwined impacts of the Pleistocene and Sub-Recent uplift and recent glaciation, and followed by the gradational work of the streams which have added to their distinctive characteristics. The foot hills or the sloping Karewas have been continually raised up, tilted and folded along with the upheaving range.



Source: Generated from SOI toposheets, 1971

Map 2.1

There are some hills which rise above the 3,000 m elevation. The highest peak in the foot hills is located in Zugu Kharyan Forest on north-west of Sukhnag in the Upper foot hills in Budgam district.

The sloping Karewas are the gradational features formed due to the collective work of glaciers and streams descending down from the Pir Panjal range and the Lake itself. So, they are formed of fluviatile, glacial and lacustrine deposits, and represent a relief feature of immense geographic and socio-economic significance. The sloping Karewas are the dominant type of Karewas in Kashmir and are longitudinal in form in against the flat-topped Karewas. Their gently sloping surfaces have been cut into deep ravines, ranging from 50 to 150 meters in depth by ongoing rigorous fluvial action. The streams like Bring, Sandran, Vishav, Romoshi, Rambiara, Doodhganga, Sukhnag, and Ferozpur and their tributaries rising from the upper reaches of the Range are active in reshaping and grading the foot hills through different gradational actions. Along the edge of the hills of Pir Panjal, the sloping Karewas have been dissected into a multitude of steep-sided ravines, giving the landscape a typical look of immaturity.

The Karewa deposits in the Kashmir valley have been conventionally divided into two stages, lower and upper, representing argillaceous and arenaceous facies respectively. The upper Karewas are less fossiliferrous than the lower Karewas, and are separated by an unconformity representing an erosional interval as a result of which about 600 m of the lower Karewas was eroded from the crust of the anticlinal fold, as observed in Hirpur of Shopian tehsil along Rembiara River. The thickest of the succession of Karewas is exposed in Pakharpur and therefore, referred to as Pakharpur Formation; here the Karewas rest over the Panjal volcanics with an angular unconformity. The entire belt of the lower Karewas has been exposed by the rivers starting from the south such as Veshav, Rembiara, Romushu, Dodhganaga, Shaliganga, Boknag nar and Ningli, thus exposing lower Karewa sections at Aharbal, Anantnag, Arigam, Baramulla, Ichguz, Aglar, Wapzan, Hirpur, Naugam, Nichihom, Pakharpur, Shupian and Yusmarg (Parray, 2011).

2.1.3. Geological Formations

The foot hills of Pir Panjal range in Kashmir valley located roughly between the elevations of 1800-3000 meters above mean sea level exhibit a varied geomorphology, stratigraphy and lithology almost like any other piece of landscape on the earth's surface. So far the stratigraphic and geological evolution of the foot hills is concerned; they show almost a complete succession of systems/series of respective periods/epochs with their unique formations/beds running from Paleozoic Era onwards (Raza, *et al*., 1978) (Map 2.2). The chrono-stratigraphic and lithological setup of the foot hills are briefly discussed below:

Cambrian System

The Cambrian system occupies a very small area of the study area and is represented by the fossiliferrous rocks which include the soft quartzites, clays and colitic limestone containing trilobites.

Ordo-Silurio-Devonian System

Ordovician, Silurian and Devonian systems lie conformably above the Cambrian system in a successional style. The Silurian deposits are hidden under recent alluvium of Arpat stream and its tributaries. The rock formations of Ordovician system formed in Ordovician period consist of arenaceous and ferruginous shales, quartzose greywackes and limestones. The thick quartzites, unfossiliferrous, beds lying conformably on the Silurian strata are assigned a Devonian origin.

Carboniferous System

It comprises of four sub-series as given under:

Syringothyris Limestone (Lower Carboniferous) Series

Next in the order of superposition is a series of limestone strata lying conformably over the Devonian quartzites.

Fenestella Shales

Overlying the upper beds of the Syringothyris limestone there comes some thickness of unfossiliferrous quartzites and shales before the first beds of the characteristic Fenestella bearing strata begin.

The Panjal Volcanic Series

Rocks of this series are divisible into two broad sections : the lower—a thick series of pyroclastic slates, conglomerates and agglomeratic products, some thousand feet in thickness, and called by Middlemiss the " Panjal agglomeratic slates " ; and the upper—the " Panjal traps," an equally thick series of bedded andesitic traps generally overlying the agglomerates (Wadia, 1981).

Gangamopteris Beds

The Panjal traps are directly and conformably overlain in several parts of Kashmir by a series of beds of siliceous and carbonaceous shales called as gangamopteris beds containing the ferns Gangamopteris and Glossopteris.

Permian System

The Zewan Series

The Permo-Carboniferous series of deposits, the local representative of the Productus limestone of the Salt-Range and of the Productus shales of Spiti, have been known since an early date as the Zewan beds, from their exposure at the village of Zewan in the Vihi area.

Triassic System

In the present study area, the formations of the Triassic period spread over a long stretch and are exposed in the Pir Panjal precipices facing the Jhelum valley and many other places outside the study area (Raza, *et al*., 1978).

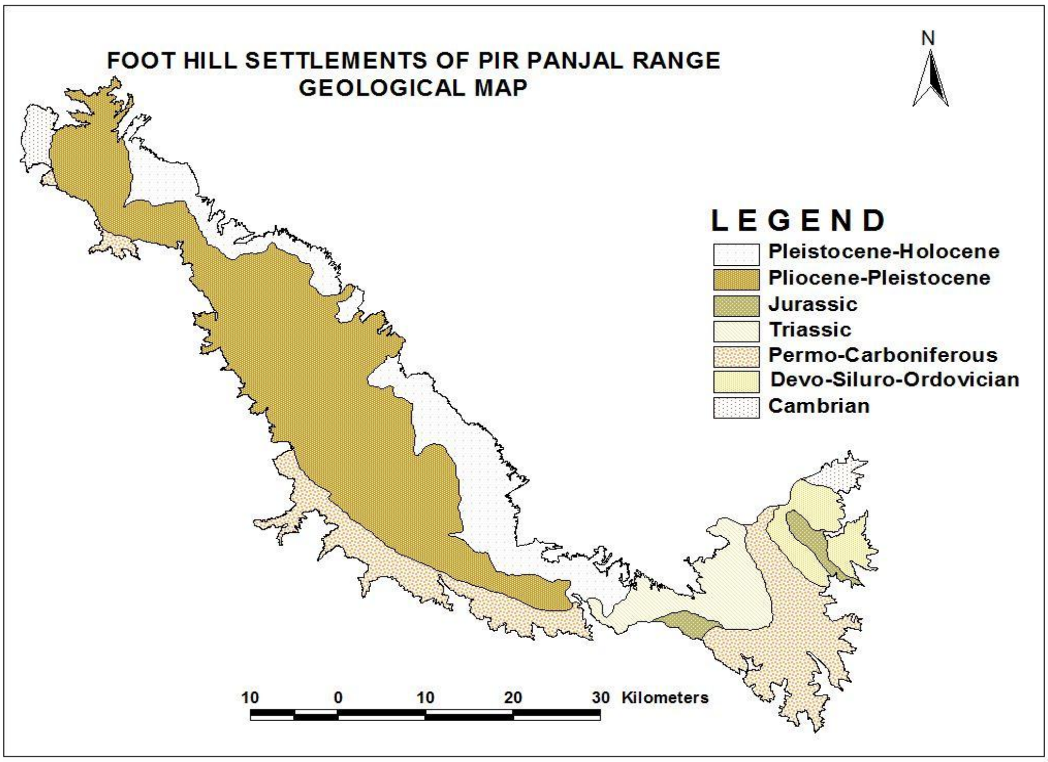
Jurassic System

The Jurassic horizon is believed to be fairly extensive, perhaps stretching up to Gulmarg from Kokernag under glacial and Karewa deposits of the Pliocene-Pleistocene periods.

Pleistocene-Holocene (Recent)

Pleistocene or post-Pliocene deposits, of the nature of fluviatile, lacustrine or glacial, have spread over many parts of Pir Panjal and occupy a large superficial extent hiding the preceding geological set-up of the area. These superficial deposits include Karewas, fluviatile and lacustrine deposits of older alluvium embedded with terminal moraines and the glacial clays, younger alluvium of the low-lying tracts and the glacial and para-glacial materials of the river terraces in the upper valleys of streams.

In the foot hills of the Pir Panjal range of Kashmir valley, the Holocene system is represented by the recent alluvium deposited by rivers often annually during flooding at elevations from 1,800-3,000 meters above mean sea level. It is formed of sediments deposited by the streams coming down from the upper reaches of Pir Panjal.



Source: Generated from SOI Geological Map of J & K State, 1969

Map 2.2

2.1.4. Soils

The soils of the concerned area vary in origin from alluvial to lacustrine and glacial (Raza, *et al*., 1978). Their present day status is mainly attributed to the climatic processes than the geological controls. They have experienced the different phases of fluvial and glacial cycles. Presently, different gradational processes such as frost action, chemical decomposition, thermal expansion, mass wasting, fluvial and aeolian erosion and deposition are responsible for shaping them. Man as a geomorphic agent is playing tremendous role in changing the character of the soils.

Since, foot hills of Pir Panjal range in Kashmir Valley are sloping Karewas, they have broadly a variable mantle of Karewa soils mainly in the Lower Foot Hills and Highland soils in the Upper Foot Hills. The Karewa soils are mostly composed of silts and are poorer. By and large, these soils are devoid of vegetal cover and lack in organic matter. The moisture retaining capacity of the soil is poor as the upper layer has a high sand content.

The highland soils are deficient in bases and become more and more acidic as altitude and vegetal cover increases. They have many differences on account of site, nature of slope and altitude. They are generally thin and immature soils, but the valleys and flat lands, even at high altitudes, may have a deep soil layer with good humus content. These soils have a higher tendency to leach.

So far the local classification of soils of this area is concerned; the Kashmiri peasant recognizes three main types of soils, namely, gurti, bahil and sekil. The gurti literally meaning silt is a fertile soil with high content of clay and silt and high water retaining capacity. It is found in some areas of LFHs-1 and along the stream valleys.

The bahil soils, next in importance to gurti are excellent loams, though proportion of silt, clay and sand varies from place to place. The proportion of silt and clay decreases with increasing distance from the gurti soil zone.

The sekil soils are coarse in texture. These are rich in humus since most part of it lies under the forests and give promising results when put to cultivation under assured water supply.

The present study is based on the soil classification given by Indian Council of Agricultural Research (ICAR), Nagpur in 2010. The ICAR have divided soils of Jammu and Kashmir state in 2010 into 140 classes plus one i.e., Glaciers, Water bodies, etc. on the basis of climatic conditions and physical character of the soils. In the present work, the soil map produced by ICAR, 2010 was a bit modified and eight soil types were identified (Table 2.1 and Map 2.3). These are briefly explained as given below:

Table 2.1: Soil types with Codes and Characteristics

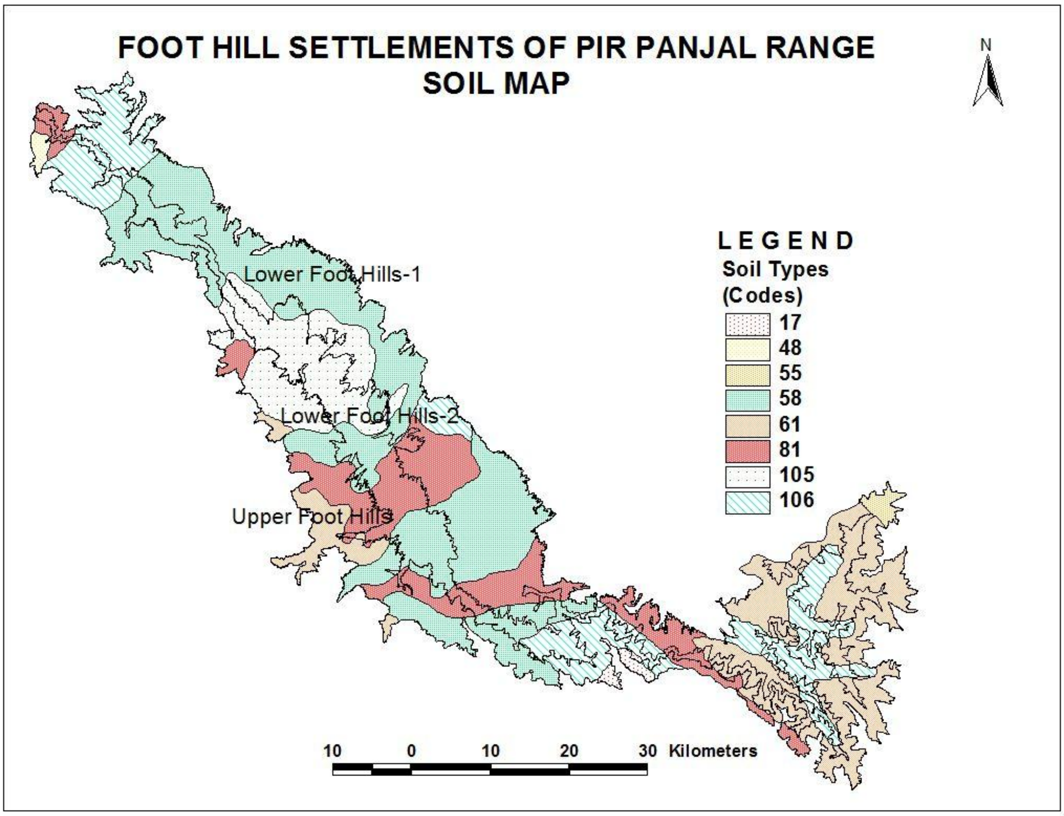
Code	Description	Soil Type
17	Dominantly rock outcrops; associated with shallow, loamy, calcareous soils on steep to very steep slopes with loamy surface, strong stoniness and severe erosion	Lithic Cryorthents
48	Medium deep, moderately well drained, mesic, fine loamy soils on steep slopes with loamy surface and severe erosion; associated with deep, somewhat excessively drained, fine soils on steep slopes with loamy surface, severe erosion and slight stoniness	Fluventic Eutrochrepts/ Dystric Eutrochrepts
55	Deep, well drained coarse-loamy soils on gentle slopes with loamy surface, moderate erosion and slight gravelliness; associated with deep, well drained, coarse loamy, calcareous soils with loamy surface, moderate erosion and slight gravelliness.	Typic Cryofluvents
58	Deep, well drained, calcareous, fine-loamy soils on nearly level slopes with loamy surface and very slight erosion; associated with deep, moderately well drained, calcareous, coarse-loamy soils with loamy surface and moderately shallow ground water.	Typic Eutrochrepts/ Fluventic Eutrochrepts
61	Medium deep, well drained, loamy-skeletal soils on moderate slopes with loamy surface, severe erosion and strong stoniness; associated with medium deep, well drained, fine-loamy soils with loamy surface, moderate erosion and moderate stonniness.	Typic Udorthents/ Dystric Eutrochrepts
81	Deep, moderately well drained, fine soils on very gentle slopes with loamy surface; associated with deep, well drained, fine-loamy soils with loamy surface.	Typic Hapludalfs/ Dystric Eutrochrepts
105	Medium deep, excessively drained, coarse loamy soils, on steep slopes with loamy surface, severe erosion and moderate stonniness; associated with deep, well drained, fine-loamy, calcareous soils with loamy surface and moderate erosion.	Typic Udorthents/ Typic Eutrochrepts
106	Medium deep, well drained, fine loamy soils on moderate slopes with loamy surface and moderate erosion; associated with shallow, excessively drained, loamy soils with loamy surface, moderate erosion and strong stonniness.	Dystric Eutrochrepts/ Lithic Udorthents

Source: Modified from Soil Map of J&K State by ICAR, Nagpur-2010

Since, the above captioned soil types are of different characteristics they exercise different influences on the behavior of trace elements in them. Theoretically, the trace element holding or retaining capacity of the soils keeping in view their totality of characteristics is highlighted as:

58 > 81 > 106 > 105 > 61

The soil types coded with 17, 48 and 55 have been omitted in the above equation for they occupy only a small uninhabited portion of the study area. The above mentioned relationship may be punctuated and interrupted due to other soil parameters such as organic matter in the soils, pH and other chemicals. The local topography and moisture content also play an important role.



Source: Modified from Soil Map of J & K State, ICAR, Nagpur-2010

Map 2.3

2.1.5. Natural Vegetation

The differentiation of physical configuration, altitude, aspect, soil and climatic variables give rise to different assemblages and complexes of natural vegetation of varying form, size and type in the foot hills both horizontally and vertically. The broad-leaved tropical forests which were once a dominant climax community in the foot hills have been taken over by the temperate conifers due the uplift of the Pir Panjal bringing a change in climate from subtropical to temperate (Puri, 1960 cited in Raza, *et al.*, 1978). Man himself being the most potent agent of change has tremendously intervened in changing the picture of natural fauna in the foot hills. The human beings have modified the natural vegetation in the foot hills for timber, grazing, settlement expansion, fuel wood, horticulture and the like uses. The natural vegetation of foot hills comprises of two broad types of forests and grasslands. There are three main factors which explain the altitudinal zoning of vegetation: (i) locational factors, such as terrain, slope and soils; (ii) altitude; and (iii) aspect.

2.1.6. Surface Water Resources (Streams)

The major stream that drains the Kashmir valley is the River Jhelum. Its tributaries drain the foot hills. Certain first and second order streams join together around 3,000 m AMSL in Waniar Reserved Forest and at around 1,850 m AMSL near Manzmuh Village of Anantnag District in Lower Foot Hills flow as a single stream known as Veth or Jhelum. It first runs in north-easterly direction till it reaches the NH-1A on its left and then flows in north-westerly direction on left side (west) of NH-1A. The following tributary streams drain the foot hills of Pir Panjal range (Raza, *et al*., 1978).

The Bring: The headstreams of the Bring receive the snow-melt from a vast area in the Pir Panjal around 3,500 m AMSL. After the confluence of the Ahlan and the Razparyin near the village of Vailu, the river is called the Bring.

The Sandran: Having its birth below the Kaukut peak in the Pir Panjal, the river passes through a deep carved channel, studded with big boulders from its source to a point close to Verinag. Below Verinag, its bed is aligned parallel to that of the Jhelum. It flows only for about twenty two kilometers in the study area.

The Vishaw: The Vishaw has its source from the Konsar Nag at an altitude of 3,840 m AMSL. It flows for about nineteen kilometers within the foot hills.

The Rembiara: The source of Rembiara lies in the Rupri ridge which is the culmination of the Pir Panjal towards west, its main feeders originating from Rupri peak and the Bhag Sar Lake on the one hand, and the Pir Panjal and the Nabba Pir pass on the other. The Rembiara traverses a course of thirty three kilometers before leaving the foot hills at Sheikh Pora.

Romushi: The snowy peak of Kharmarg (4,603 m) near Nabba Pir pass in the Pir Panjal is the source region of the primary feeders of Romushi. The main Romushi stream runs only for five kilometers in the foot hills.

The Dudhganga: Originating below the lofty mountain peak of Tatakuti in the Pir Panjal range, the Dudhganga flows as Dudhganga Nala for about twenty two kilometers in the foot hills and runs in the north-north-east direction.

The Shaliganga: The Shaliganga has its origin close to the Dudhganga. It flows for about twenty one kilometers and leaves the foot hills near Kashi Pora.

The Sukhnag: Draining the slopes of Pir Panjal, various mountain torrents unite themselves into the Sukhnag. It leaves the foot hills at Kawgund after flowing for about twenty kilometers. It drains main portion of the Toshmaidan area.

The Firozepura: The Firozepura Nala drains Tangmarg area. It passes through a sandy bed and flows for about twenty kilometers. It bifurcates in the Lower foot hills near Kulhama.

The Ningal: The Ningal is the last major tributary of Jhelum originating from the Pir Panjal range. Its feeders rise below the Khan Pathri (3,809 m) and Apharwat (4,141 m) peaks of the Pir Panjal above Khelanmarg. It flows for about thirteen kilometers in the study area and leaves at Kalantra Bala.

The Mundri: The Naubal Nala and Sultanpura Kol are last two significant streams that rise in the Upper foot hills and drain the northern most part of the foot hills of Pir Panjal range in Kashmir valley. They join together and once they leave the foot hills, they flow as Mundri Nala.

The surface water resources in the foot hills are very enormous. The total run-off that moves down the rivers or accumulates in large number of marshes and lakes is a powerful indicator of this plentiful supply. The above mentioned river systems are fed either by springs/rain or snow or both. The flow is poor during winter as most of the precipitation comes in the form of snow. These water sources move over different geological/pedological strata and attain the respective character in their composition. Since, these water sources are used for different domestic purposes especially drinking, cooking and bathing, they may have a control on human health of the respective areas. About 30% of the people in sample villages depended on these water sources.

The map 2.4 gives the general overview of the behavior of the main streams in the foot hills of the Pir Panjal range in Kashmir valley.

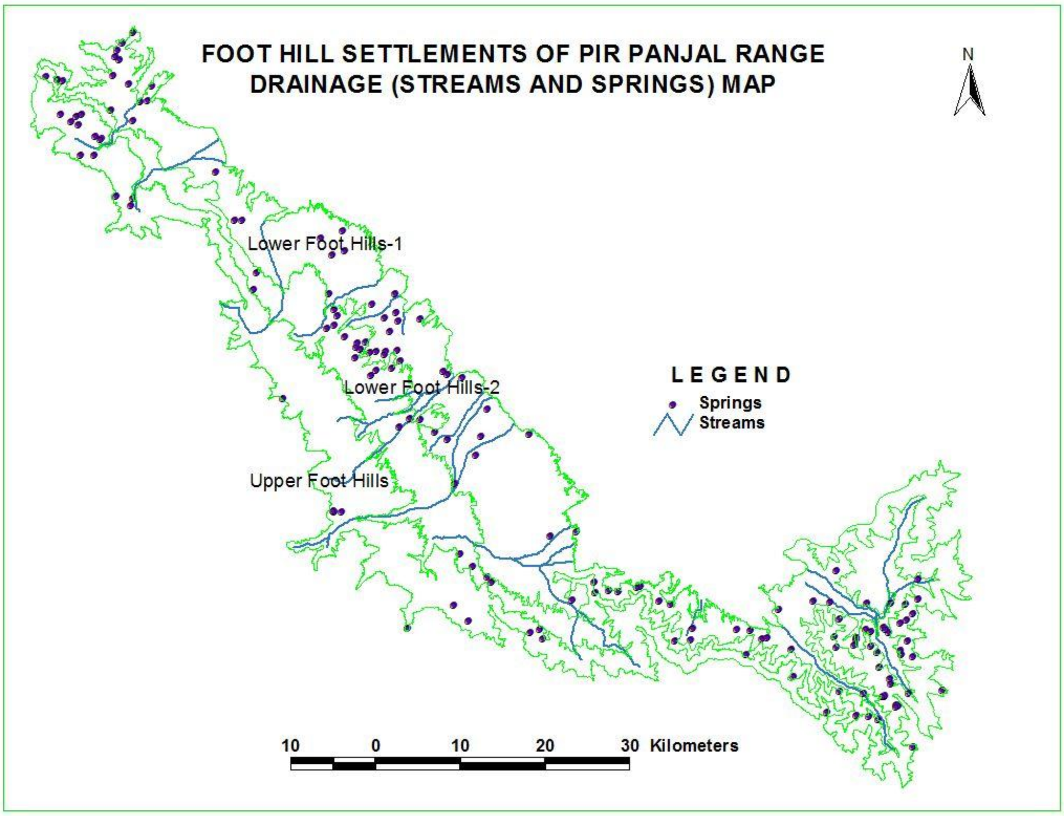
2.1.7. Groundwater Resources/Springs

Springs are assumed to be stable ecosystems and once ground water flows as a spring it loses the natural protection provided by the overlying rock layers and is more vulnerable to contamination threats from surface and atmospheric conditions (Vanderkamp, 1995). Sub-surface water (spring water) though believed to be of better quality is now losing quality at the selfish interests of man.

The foot hills have a promising abundance of groundwater resources (Map 2.4). Four types of springs exist in the area: karst, alluvial, karewa and warm springs. It has been revealed that rock joints and fractures, obviously, provide the most significant structural control for the very existence of the springs in the area. These planes establish a hydrological continuity between the recharge zones at higher altitudes and the discharge sites at the lower altitudes and valley floor (Jeelani, 2010).

People in the foot hill settlements are also dependent on the groundwater for their sustenance either completely or partially. About sixty five to seventy percent (65-70%) of the people in sample villages depended on the spring water. The groundwater gets chemically changed through both natural and human sources. The groundwater comes through variable geological strata and dissolves the minerals in contact. This chemical process changes its chemical status and people take this water mostly without any prior treatment. Also, the intervention through different human activities, the spring water gets polluted. Different types of chemicals/elements are required by human body in required amounts and once the healthy character of water gets impaired, human health deteriorates.

The maximum numbers of springs were identified in the LFHs-1 with decreasing number in the higher altitudinal zones. The surface water seeps in the permeable beds of the mountain and karewa geological formations and moves down the underground slope oozing and gushing out in the low lying tracts. The map 2.4 gives the spatial distribution of natural springs in different altitudinal zones of the foot hills of Pir Panjal range in Kashmir valley.



Source: Generated from SOI Toposheets, 1971

Map 2.4

The demand for underground water is increasing in the area since the surface water sources are becoming impure and the population is increasing in number. Although the springs have served as traditional water sources for the inhabitants for centuries, but little attention is given for their cleaning and development. As the springs are mostly in remote areas, due to the lack of awareness of water quality the families living nearby use the springs for drinking, cooking, bathing, washing and other domestic purposes and the government hardly bothers.

The water quality of the springs in the foot hills of Pir Panjal range is deteriorating day by day. It has been found by Rather et al. (2014) that the water quality of some of the springs has been deteriorating because of human impact. The bio-chemical characteristics of the spring waters are changing. The springs especially which are located at lower altitude than the surrounding human settlements are experiencing threat of eutrophication and increase in the coliform count. It has been noted that the incidence of water borne diseases is very high.

The spring waters of the area are deficient in essential trace elements. Hajam et al. (2015) found that the spring waters in the foot hills of Pir Panjal range in Anantnag district are deficient in essential trace elements and there is a potential threat to the health of the human population of the area. It was revealed that the average concentrations of zinc, copper and iodine (Zn: 0.0006 mg L^{-1}; Cu: 0.002 mg L^{-1}; I: 1.6-4.2 µg L^{-1}) are less than the required and acceptable limits (BIS: Zn: 5 mg L^{-1}; Cu: 0.05 mg L^{-1}; ICMR: I: 150 µg d^{-1}) for human beings.

2.1.8. Climate

The general climate of the foot hills is like the climate of the Kashmir valley as a whole. But, there are certain variations in the total monthly and annual precipitation and temperature. Like other parts of the Kashmir valley, the climate of the foot hills is characterized by a mild summer, not too much vigorous winter and absence of regular rainy season with exception of a few small valleys like Waltengo and Gulmarg. The locational and physiographic setting of the valley has a tremendous control on its climate including the foot hills. The Pir Panjal range acts as an effective barrier to the summer monsoons and the foot hills experience a rain shadow-effect. But, it guides the Western disturbances and makes them to precipitate over a long and wide area along the Pir Panjal. The climate of the foot hills is sub-Mediterranean in nature on account of its rainfall distribution.

2.2. SOCIO-ECONOMIC SETTING

2.2.1. Population Distribution and Density

In the area under study, population distribution and density are uneven. There are about 8, 44,543 people occupying an area of 2, 255.36 sq. km. The population density is 374.46 persons per sq. km. About 99% of the population is distributed in Lower foot hills (1, 800-2, 400 m AMSL) of the area and only less than 1% live in the Upper foot hills (2, 400-3, 000 m AMSL) with a population density of 580.30 persons km^{-2} and 6.07 persons km^{-2} respectively (Table 2.2). Within the LFHs, about 73% population of the total population of the area lives only in LFHs-1 (1, 800-2, 100 m AMSL). The possible factors responsible for the concentration of population in LFHs especially LFHs-1 are availability of land area for cultivation, horticulture, construction of settlements and roads, frequent services of transport, health care, information, education, market and banking, availability of daily jobs, and the like.

The sample villages under study support a population of 29, 949 persons on an area of 2740.3 km^{-2} and so the density is 10.93 persons km^{-2}. Out of the total population in the sample villages, more than 95% population lives in LFHs and less than 5% in the UFHs with population density of 10.81 persons km^{-2} and 14.23 persons km^{-2} respectively (Table 2.3). Likewise household distribution was found uneven with maximum concentration in LFHs than UFHs (Table 2.2).

Table 2.2: Demographic and Socio-Economic Profile

Macro Regions	Micro Regions	Total Population (%)	Population Density	Sex Ratio	Literacy Rate	Working Population (%)	Non-Workers (%)
LFHs	LFHs-1	6, 12, 732(72.55)	711.30	924.81	46.78	30.99	69.01
	LFHs-2	1, 26, 904(26.87)	387.56	917.11	36.45	31.07	68.93
Total		8, 39, 636(99.42)	580.30	923.16	45.04	31.01	68.99
UFHs	UFHs	4, 907(0.58)	6.07	935.35	43.03	59.67	40.33
Grand Total		8, 44, 543(100)	374.46	918.69	45.02	31.18	68.82

Source: Computed from Census of India, 2011

Table 2.3: Population Distribution, Density and Sex Composition in the Sample Villages

Macro Regions	Micro Regions	Sample Sites	Total Population (%)	Area (sq. km.)	Density (persons/sq. km.)	Male Population	Female Population	Sex Ratio
LFHs	LFHs-1	SS1-ANG	516(1.72)	75.3	6.85	272	244	897.06
		SS2-ANG	3004(10.03)	169.6	17.71	1576	1428	906.09
		SS3-KUL	803(2.68)	126.7	6.34	432	371	856.79
		SS4-KUL	490(1.64)	50.6	9.68	238	252	1058.82
		SS5-SHO	289(0.96)	36.4	7.94	142	147	1035.21
		SS6-SHO	1348(4.50)	265.9	5.07	677	671	991.14
		SS7-PUL	907(3.03)	32.0	28.34	451	456	1011.08
		SS8-BUD	2575(8.60)	175.2	14.70	1328	1247	939.00
		SS9-BUD	539(1.80)	88.2	6.11	286	253	884.61
		SS10-BAR	162(0.54)	22.7	7.14	79	83	1050.63
		SS11-BAR	442(1.48)	51.8	8.53	222	220	990.99
	Total		11075(36.97)	1094.4	10.12	5703	5372	941.96
	LFHs-2	SS12-ANG	1578(5.27)	73.6	21.44	812	766	943.35
		SS13-ANG	1412(4.71)	90.6	15.58	732	680	928.96
		SS14-KUL	538(1.80)	26.7	20.15	279	259	928.31
		SS15-KUL	1479(4.94)	93.1	15.89	757	722	953.76
		SS16-SHO	3819(12.75)	413.2	9.24	1926	1893	982.86
		SS17-SHO	1714(5.72)	159.0	10.78	884	830	938.91
		SS18-BUD	4191(13.99)	373.5	11.22	2220	1971	887.84
		SS19-BUD	465(1.55)	134.8	3.45	247	218	882.59
		SS20-BAR	1945(6.49)	146.1	13.31	978	967	988.75
		SS21-BAR	326(1.09)	36.4	8.96	171	155	906.43
	Total		17467(58.32)	1547	11.29	9006	8461	939.48
Total			28542(95.30)	2641.4	10.81	14709	13833	940.45
UFHs	UFHs	SS22-ANG	1109(3.70)	76.9	14.42	571	538	942.21
		SS30-BAR	298(1.00)	22.0	13.55	156	142	910.25
	Total		1407(4.70)	98.9	14.23	727	680	935.35
Total			**29,949(100)**	**2,740.3**	**10.93**	**15436**	**14513**	**940.20**

Source: Computed from Census of India, 2011

2.2.2. Sex Composition

Sex composition is numerically expressed as sex ratio. In India, it is the number of females per thousand males. The sex ratio of the area was 918.69. The sex ratio in the UFHs was more favorable (935.35) as compared in the LFHs (923.16).

At the sample village level, sex ratio of the area (940.20) was comparable to the sex ratio of India (940). There was a little variation in the sex ratio of the LFHs (940.20) and the UFHs (935.35). In the foot hills at sample village level, sex ratio varied from 856.79 to 1058.82. The sample villages in which the sex ratio is below the normal may be ascribed to the low care of and negligence of women at the hands of ill-thought men at different stages of life and hence high female mortality than the males. The socio-economic background may also be counted as a potent factor in skewing the sex ratio of the area.

2.2.3. Literacy Composition

Since the area under study is rural in character with low standard of living, lack of urbanization and technological development, it revealed low literacy rate of 45.02%. The literacy rate of LFHs (45.04%) was relatively higher than the UFHs (43.03%) (Table 2.2). It can be attributed to disparity in the standard of living, availability of transportation and education services and exposure of the people.

At sample village level, the area revealed a literacy rate of 39.27% with relatively high percentage of literates in LFHs (42.31%) than the UFHs (34.54%) (Table 2.4). In the sample villages, percentage of literate population to total population varied from 29.74% to 67.13%. The variations in literacy with respect to gender were also found with lesser number of literates among women.

Table 2.4: Household Distribution and Density and Literacy Composition and Rate

Macro Regions	Micro Regions	Sample Sites	Number of Households	Density (Households /sq. km.)	Total Literate Population	Male Literate Population	Female Literate Population	Literacy Rate
LFHs	LFHs-1	SS1-ANG	77	1.02	228	136	92	44.19
		SS2-ANG	519	3.06	1656	970	686	55.13
		SS3-KUL	136	1.07	370	257	113	46.08
		SS4-KUL	82	1.62	234	137	97	47.76
		SS5-SHO	47	1.29	194	104	90	67.13
		SS6-SHO	226	0.85	785	449	336	58.23
		SS7-PUL	142	4.44	485	276	209	53.47
		SS8-BUD	329	1.88	825	524	301	32.04
		SS9-BUD	93	1.05	171	107	64	31.73
		SS10-BAR	27	1.19	89	53	36	54.94
		SS11-BAR	80	1.54	247	145	102	55.88
	Total		1758	1.61	5284	3158	2126	47.71
	LFHs-2	SS12-ANG	292	3.97	515	313	202	32.64
		SS13-ANG	252	2.78	676	391	285	47.88
		SS14-KUL	84	3.15	160	103	57	29.74
		SS15-KUL	274	2.94	614	351	263	41.51
		SS16-SHO	609	1.47	1542	900	642	40.38
		SS17-SHO	297	1.87	579	363	216	33.78
		SS18-BUD	524	1.40	1322	815	507	31.54
		SS19-BUD	60	0.45	160	118	42	34.41
		SS20-BAR	314	2.15	1040	609	431	53.47
		SS21-BAR	51	1.40	183	114	69	56.13
	Total		2757	1.78	6791	4077	2714	38.87
Total			4515	1.71	12075	7235	4840	42.31
UFHs	UFHs	SS22-ANG	143	1.86	332	187	145	29.93
		SS30-BAR	43	1.95	154	96	58	51.68
	Total		186		486	283	203	34.54
Total			4701	1.72	11761	7118	4643	39.27

Source: Computed from Census of India, 2011

2.2.4. Economic Composition

The economic composition of the population unfolds a gateway for understanding the socio-economic development of the area. It includes both economically active population (working population) and economically non-active population (non-working population). The size of the working force is mainly determined by the total population base but the age structure and demographic regime are also important. There were only one-third (31.18%) of the total population involved in different economic activities (Table 2.2). About 68.82% population constituted the non-working population.

At the sample village level, 30.22% population constituted the total working population in the area with 30.34% in LFHs and 27.57% in UFHs. The working force varied from 18.18-55.31% in SS18-BUD and SS13-ANG respectively (Table 2.5). Among the working population, there was greater percentage of marginal workers than the main workers. The non-workers constituted about more than double the working population. The gender variations were observed quite prevalent.

Table 2.5: Economic Population Composition

Macro Regions	Micro Regions	Sample Sites	Total Working Population (%)	Main Workers	Marginal Workers	Non-Workers
LFHs	LFHs-1	SS1-ANG	159(30.81)	33	126	357
		SS2-ANG	1079(35.92)	510	569	1925
		SS3-KUL	368(45.83)	69	299	435
		SS4-KUL	207(42.24)	68	139	283
		SS5-SHO	58(20.07)	56	2	231
		SS6-SHO	389(28.86)	343	46	959
		SS7-PUL	266(29.33)	190	76	641
		SS8-BUD	664(25.79)	278	386	1911
		SS9-BUD	163(30.24)	136	27	376
		SS10-BAR	45(27.78)	36	9	117
		SS11-BAR	109(24.66)	109	0	333
	Total		3507(31.66)	1828	1679	7568
	LFHs-2	SS12-ANG	351(22.24)	332	19	1227
		SS13-ANG	781(55.31)	220	561	631
		SS14-KUL	225(41.82)	47	178	313
		SS15-KUL	677(45.77)	114	563	802
		SS16-SHO	1201(31.45)	622	579	2618
		SS17-SHO	380(22.17)	269	111	1334
		SS18-BUD	762(18.18)	276	486	3429
		SS19-BUD	142(30.54)	86	56	323
		SS20-BAR	555(28.53)	300	255	1390
		SS21-BAR	80(24.54)	69	11	246
	Total		5154(29.51)	2335	2819	12313
Total			8661(30.34)	4163	4498	19881
UFHs	UFHs	SS22-ANG	306(27.59)	158	148	803
		SS30-BAR	82(27.52)	81	1	216
	Total		388(27.57)	239	149	1019
Total			9049(30.22)	4402	4647	20900

Source: Computed from Census of India, 2011

CHAPTER-3

DATA BASE AND METHODOLOGY

To achieve the various objectives of the study, a comprehensive data base and methodology has been used and is described under the following steps:

3.1. DATA BASE

The present research work is based mainly on primary data and partly on secondary sources of data. So far the geographical-ecological approach is concerned; the main sources of trace elements are soil, drinking water and food products. Figure 3.2 shows the general data base and methodological scheme that has been applied in order to accomplish the present study. The primary data include the Survey of India toposheets on 1:50,000 scale of 1971 year (Fig. 3.1), the data regarding concentration of essential trace elements (Cu, Zn, I) in the soils and drinking waters (springs, streams and tube wells), health status of the people of the area, the dependence of people on local foods, the methods of cooking food, and the like.

SOI Toposheets of the Study Area (Number and Arrangement)

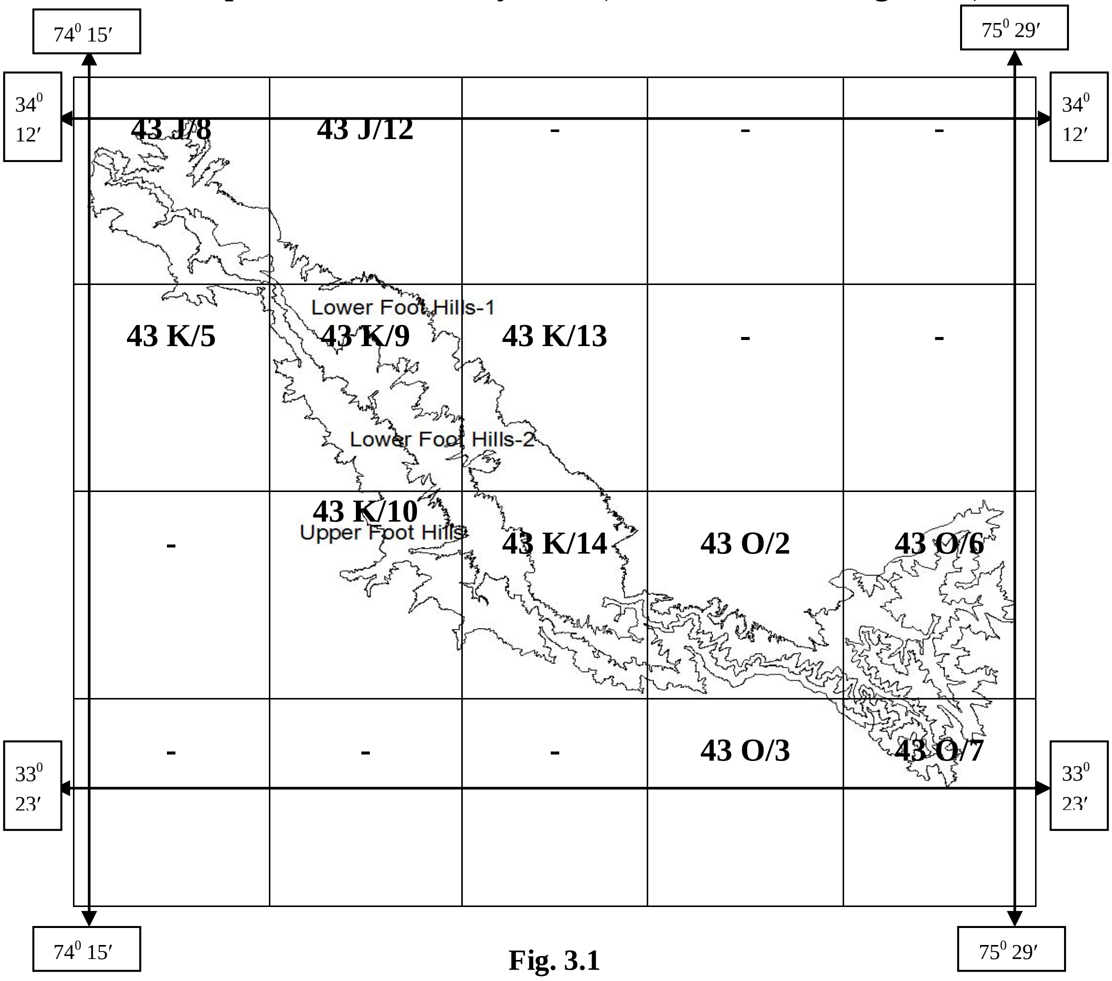


Fig. 3.1

Secondary data were collected from a variety of standard and authorized sources which include government departments, reports, manuals, research articles, etc. The data regarding population parameters of the area were taken from Census of India (2001, 2011). The Soil map of the area was generated from the Soil Map of Jammu and Kashmir prepared by Indian Council of Agricultural Research (ICAR), Nagpur-2010 and Geological strata map from the Geology Map of Jammu and Kashmir on scale of 1:22,50,000 prepared by Survey of India, 1969 (Ist Ed.). The some data regarding the human health disorders such as diabetes, thyroid disorders and the like from the concerned District Hospitals.

3.2. METHODOLOGICAL FRAMEWORK

Since the study is supposed to achieve a wide-ranging but related set of objectives, a multi-pronged strategy has been employed. The methodology has been divided into many steps based on the materials and techniques used (Fig. 3.2). The philosophical approach of the study varies from geo-ecological to geo-spatial to geo-social concerns.

The methodology is explained in systematic order as follows:

3.2.1. Delineation of the Foot Hills

Before delineating and delimiting the area of interest, the required SOI toposheets (available as soft copy) were first geo-corrected and geo-referenced in GIS environment in Earth Resource Data Analysis System (ERDAS) Imagine 9.0 software, assigning Universal Transverse Mercator with World Geocoded system (UTM WGS 84) projection parameters. The geo-referenced toposheets were then subset to facilitate an appropriate mosaic. After merging the topographic maps, the foot hills of Pir Panjal range in Kashmir were delineated by the technique of digitization in ArcView 3.2a GIS software. The contours were taken as the criterion for delineation. The base contour was taken as 1,800th m AMSL and top one as 3,000th m AMSL for almost all foot hill section of the Pir Panjal range in Kashmir valley is located within these two reference contours (Raza, *et al*., 1978). The two lateral sides of the area were linked by taking the watershed limits.

Flow Chart of Methodology

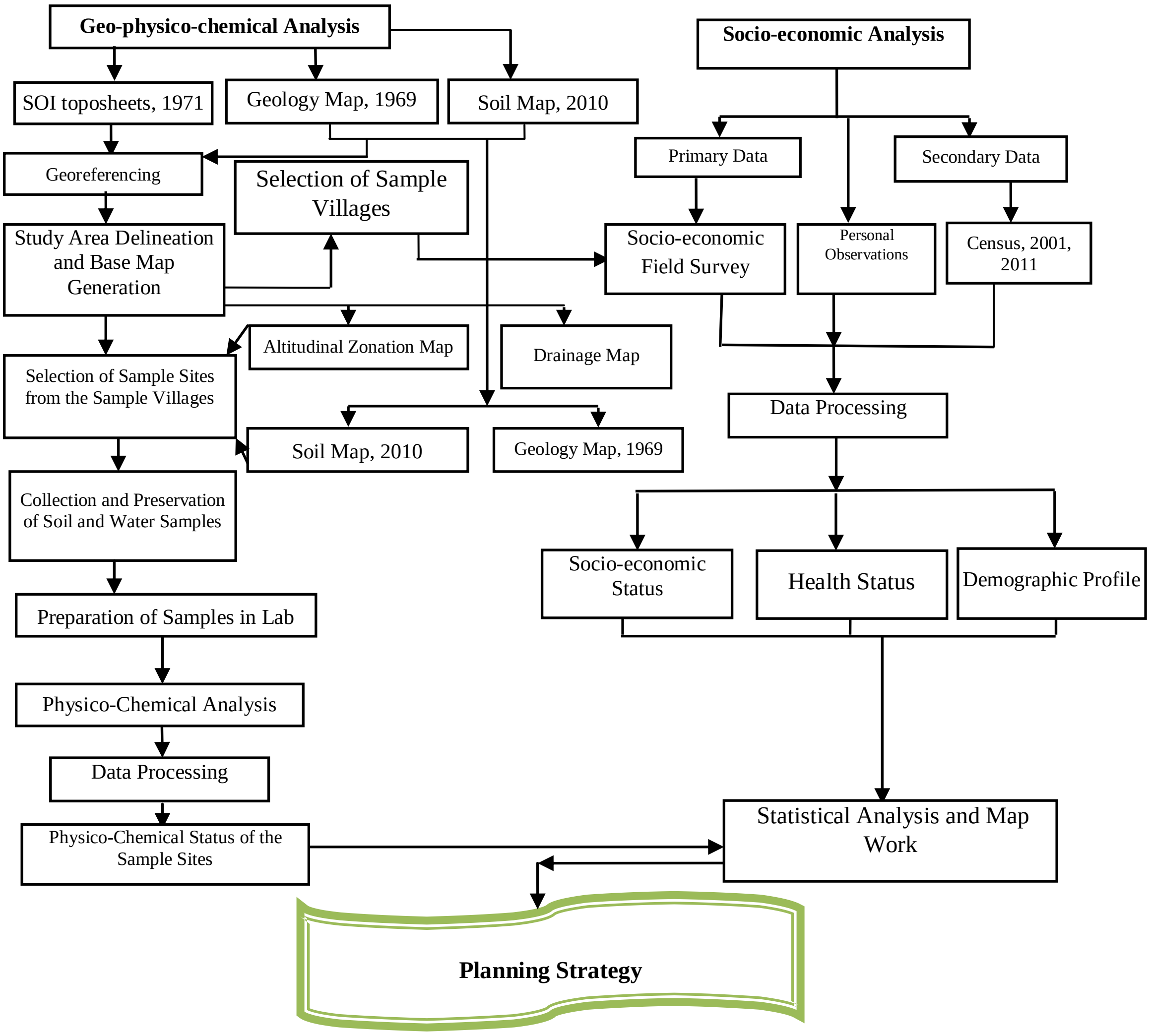
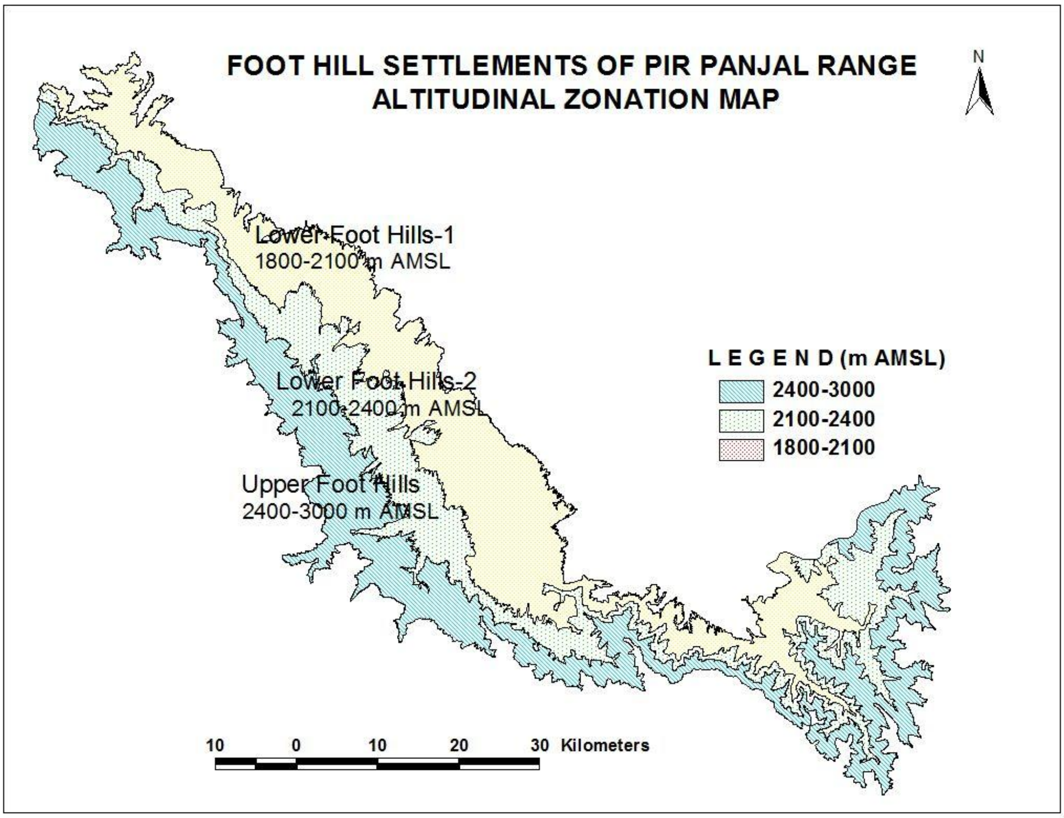


Fig. 3.2

3.2.2. Altitudinal Zonation

An altitudinal zonation map (Map 3.1) was generated through contour digitization. It shows the elevation zones, but it is two-dimensional in nature. The area under study is fairly large characterized by good altitudinal variations; it is divided into two zones called as altitudinal zones to tackle the problem under consideration at a micro-level a bit. By digitizing 2,400th m contour, the area under study was divided into two altitudinal zones. These two zones were named as Lower Foothills and Upper Foothills varying in altitude from 1,800th-2,400th m AMSL and 2,400th-3,000th m AMSL respectively. The LFHs are characterized by good permanent human occupancy while as the UFHs experience mostly seasonal human inhabitations. On this account and for the reason of comparative analysis, by digitizing 2,100th m contour, the LFHs were further sub-divided into two sub-zones namely, LFHs-1 and LFHs-2 varying in elevation from 1,800th-2,100th m and 2,100th-2,400th m to see the variability in the concentration of essential trace elements in the soils and drinking waters and their relative human health disorders at different altitudinal levels in the area.



Source: Generated from SOI toposheets, 1971

Map 3.1

3.2.3. Generation of other Thematic Map Layers

Different thematic map layers of the foot hills such as soil map, geological strata map, drainage map, were generated from secondary sources of data in GIS environment by using ERDAS Imagine 9.0 and ArcView 3.2a GIS softwares. The Soil map of the area was digitized and extracted from the Soil Map of Jammu and Kashmir prepared by Indian Council of Agricultural Research (ICAR), Nagpur-2010 and Geological strata map from the Geology Map of Jammu and Kashmir prepared by Survey of India, 1969. Finally, the essential trace element disease risk classes was prepared.

Table 3.1: Sample Frame

Macro Regions (Altitudinal Zones in meters AMSL)	Micro Regions (Sub-altitudinal Zones in meters AMSL)	Sample Sites/ Villages	District	Total No. of Households in the Sample Villages/ Towns	Number of Households Surveyed	Percentage of Surveyed Households to total Number of Households	Soil Type	Number of Soil Samples Taken	Main Water Source	No. of Water Samples Taken
Lower Foot Hills (LFHs)-1,800-2,400	Lower Foot Hills-1 (LFHs-1) -1,800-2,100	Bidder Hayat Pora	Annatnag	77	08	>10	61	01	Tap fed by a Spring	01
		Bindoo Zalan Gam		519	52	>10	106	01	Tap fed by a Stream	01
		Chandergi	Kulgam	136	14	>10	58	01	Spring	01
		Chachmolla		82	09	>10	81	01	Stream	01
		Narwaw	Shopian	47	05	>10	58	01	Tap fed by a Spring	01
		Sandho Shirmal		226	22	<10	81	01	Tap fed by a Spring	01
		Awind Gund	Pulwama	142	14		106	01	Spring	01
		Raithan	Budgam	329	33	>10	105	01	Tap fed by a Stream	01
		Mula Naru		93	09	<10	58	01	Tap fed by a Stream	01
		Tokal Pora	Baramullah	27	04	>14	58	01	Tap fed by a Spring	01
		Raj Pora Thandakasi		80	08	10	106	01	Tap fed by a Stream	01
	Lower Foot Hills-2 (LFHs-2)-2,100-2,400	Hala Pora	Anantnag	292	29	<10	61	01	Tap fed by a Stream	01
		Gaw Ran		252	25	<10	106	01	Tap fed by a Spring	01
		Marg Bal	Kulgam	84	08	<10	58	01	Tap fed by a Spring	01
		Halan		274	27	<10	81	01	Tap fed by a Spring	01
		Sedheve	Shopian	609	61	>10	58	01	Tap fed by a Spring	01
		Katho Halan		297	30	>10	81	01	Tap fed by a Spring	01
		Gurweth Kalan	Budgam	524	52	<10	105	01	Tap fed by a Spring	01
		Tala Pora		60	06	10	58	01	Tap fed by a Spring	01
		Kata Pora	Baramullah	314	31	<10	58	01	Tap fed by a Spring	01
		Takia Yousuf Shah		51	05	<10	106	01	Tap fed by a Stream	01
Upper Foot Hills (UFHs)-2,400-3,000	Upper Foot Hills (UFHs)-2,400-3,000	Raing Mandoo	Anantnag	143	14	<10	61	01	Spring	01
		Chuntwar		00	00	00	106	01	Spring	01
		Gadran	Kulgam	00	00	00	58	01	Spring	01
		Bun Chirinbal		00	00	00	81	01	Stream	01
		Bur Nar	Shopian	00	00	00	58	01	Spring	01
		Sakhianwali Nar		00	00	00	81	01	Spring	01
		Shaliganga Nar	Budgam	00	00	00	105	01	Stream	01
		Drang Forest		00	00	00	58	01	Stream	01
		Kundribal	Baramullah	43	05	>10	58	01	Stream	01
		Tre Narian		00	00	00	106	01	Spring	01
Total		31		4,701	470	10		31		31

3.2.4. Selection of Sample Sites

The Stratified Random Sampling Technique was used for the selection of sample sites (sample villages) and sample households. The sample sites were selected on the basis of altitude and soil type. Thirty one (31) sample villages/sites (Maps 3.2, 3.3 and 3.4) were selected from the whole study area. The detailed sample design/frame is given in

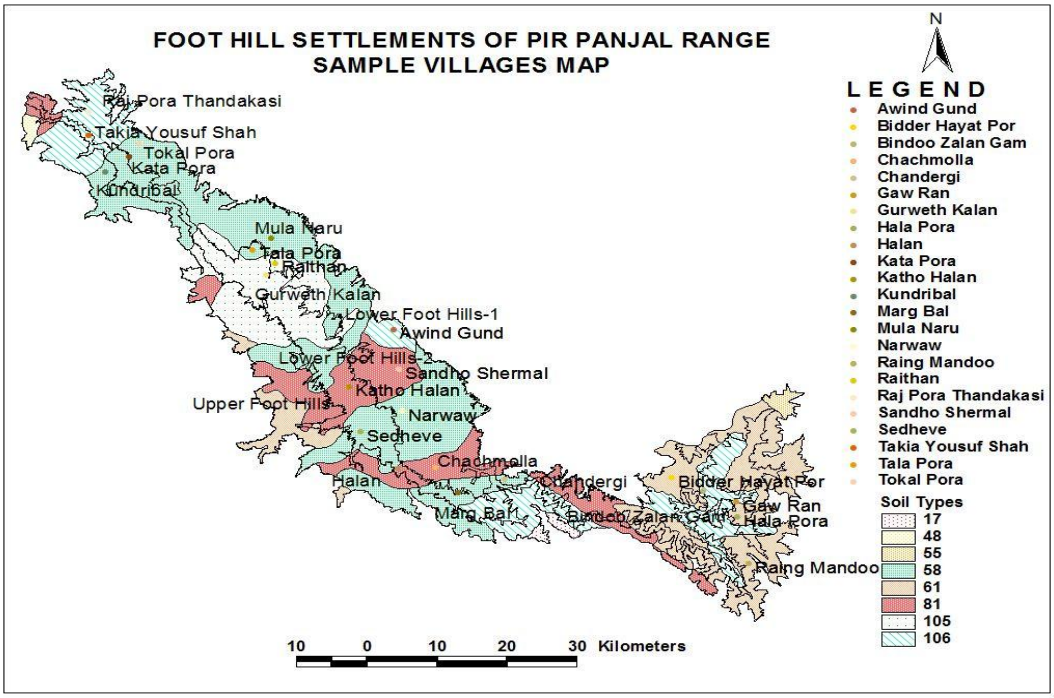
Table 3.1. For the household survey, a 10% sample size was selected. The soil samples were taken only from those soil types which are under direct or indirect human occupation. So, the soil types such as 17, 48 and 55 have been omitted.

It is very clear from the table 3.1 that one sample site/village was selected from each soil type in a district in the Lower Foot hills (in both LFHs-1 and LFHs-2) and in the Upper Foot hills. Two samples consisting of one soil sample and one water sample were taken from each sample site. Maps 3.3 and 3.4 show maps of soil and water sample sites respectively. Table 3.2 highlights the codes used for sample sites with their geo-coordinates.

Table 3.2: Sample Sites with their Codes and Geo-coordinates

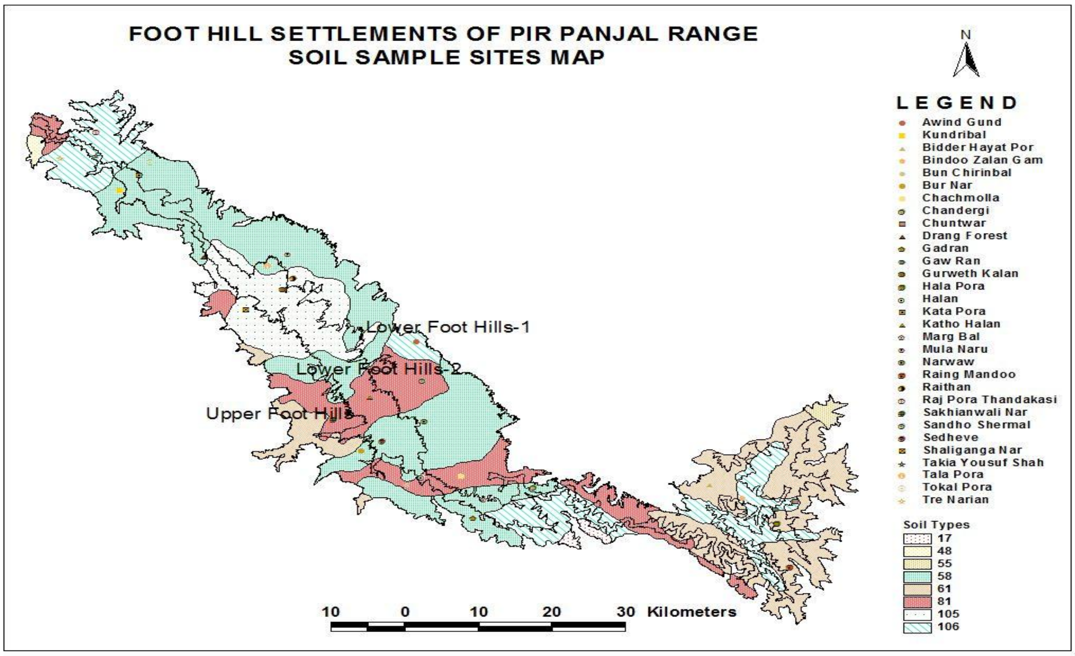
S. No.	Sample Sites/Villages	Occupancy	Codes	Geo-coordinates (Lat/Long)	Altitude (m AMSL)
01	Bidder Hayat Pora	Inhabited	SS1-ANG	33°35′58″-75°15′41″	1851
02	Bindoo Zalan Gam	-do-	SS2-ANG	33°34′50″-75°18′49″	1982
03	Chandergi	-do-	SS3-KUL	33°35′55″-75°00′41″	1862
04	Chachmlolla	-do-	SS4-KUL	33°36′52″-74°54′20″	1965
05	Narwaw	-do-	SS5-SHO	33°41′51″-74°51′14″	2055
06	Sandho Shirmal	-do-	SS6-SHO	33°45′41″-74°50′26″	1980
07	Awind Gund	-do-	SS7-PUL	33°49′12″-74°50′21″	1840
08	Raithan	-do-	SS8-BUD	33°35′05″-74°39′28″	2025
09	Mula Naru	-do-	SS9-BUD	33°57′20″-74°38′52″	2065
10	Tokal Pora	-do-	SS10-BAR	34°05′46″-74°26′51″	1890
11	Raj Pora Thandakasi	-do-	SS11-BAR	34°08′26″-74°22′08″	1950
12	Hala Pora	-do-	SS12-ANG	33°32′25″-75°21′55″	2160
13	Gaw Ran	-do-	SS13-ANG	33°33′45″-75°21′57″	2135
14	Marg Bal	-do-	SS14-KUL	33°34′34″-74°56′10″	2200
15	Halan	-do-	SS15-KUL	33°36′39″-74°50′33″	2220
16	Sedheve	-do-	SS16-SHO	33°40′06″-74°47′20″	2290
17	Katho Halan	-do-	SS17-SHO	33°44′05″-74°46′14″	2190
18	Gurweth Kalan	-do-	SS18-BUD	33°53′53″-74°38′37″	2160
19	Tala Pora	-do-	SS19-BUD	33°56′18″-74°37′14″	2160
20	Kata Pora	-do-	SS20-BAR	34°04′31″-74°25′47″	2120
21	Takia Yousuf Shah	-do-	SS21-BAR	34°06′25″-74°21′48″	2200
22	Raing Mandoo	-do-	SS22-ANG	33°28′18″-75°22′57″	2590
23	Chuntwar	Uninhabited	SS23-ANG	33°34′25″-75°23′14″	2543
24	Gadran	-do-	SS24-KUL	33°32′56″-74°55′22″	2680
25	Bun Chirinbal	-do-	SS25-KUL	33°35′51″-74°48′58″	2600
26	Bur Nar	-do-	SS26-SHO	33°39′10″-74°45′36″	2600
27	Sakhianwali Nar	-do-	SS27-SHO	33°42′05″-74°43′02″	2550
28	Shaliganga Nar	-do-	SS28-BUD	33°52′07″-74°35′15″	2500
29	Drang Forest	-do-	SS29-BUD	33°56′51″-74°31′26″	2520
30	Kundribal	Inhabited	SS30-BAR	34°03′05″-74°24′17″	2560
31	Tre Narian	Uninhabited	SS31-BAR	34°06′06″-74°18′47″	2780

Source: Compiled from SOI Toposheets, 1971 and Field Work, 2013



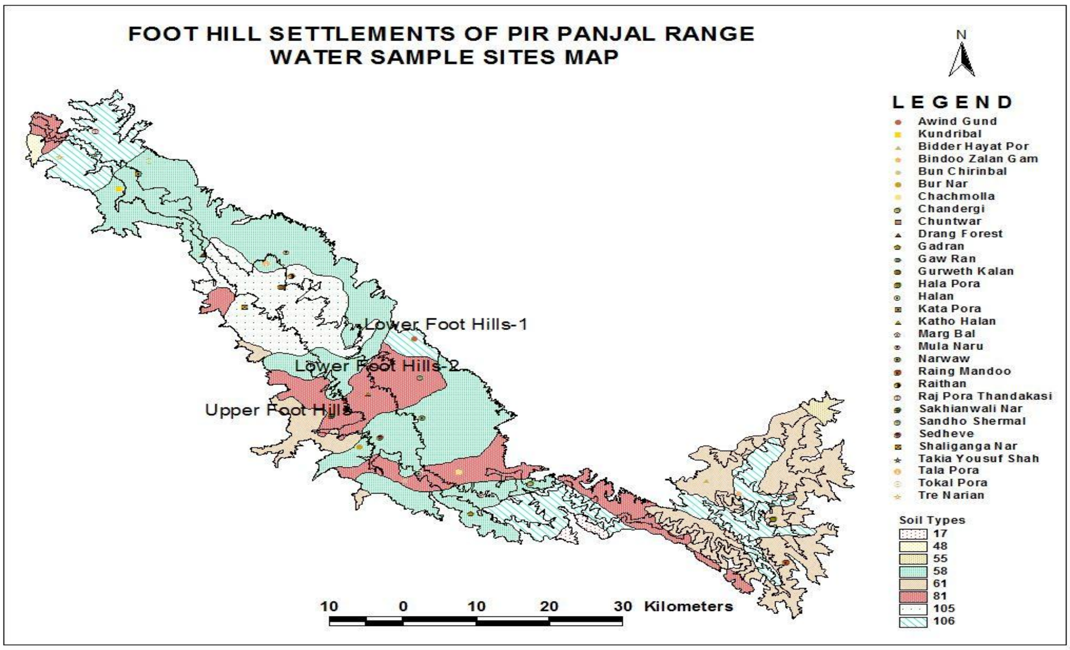
Source: Generated from SOI Toposheets, 1971

Map 3.2



Source: Generated from SOI toposheets, 1971

Map 3.3



Source: Generated from SOI toposheets, 1971

Map 3.4

3.2.5. Collection and Preservation of the Soil Samples

Soil sampling is a very tedious task. The accuracy of the final results depends a lot on the care and skill with which soil samples are taken (Motsara and Roy, 2008). The most important phase of soil analysis takes place not in the laboratory but in the field where the soil is sampled. So, proper care has been taken to take a soil sample that is best representative of the soil type in a particular altitudinal zone. In order to reduce the spatial variability and heterogeneity and to take a composite sample that may be best representative (Boulding, 1994), five sub-samples were taken from each sample site in 10 m × 10 m grid format. Four sub-samples were taken from four corners of the square and one from the center. A clean spade was used to take the sample. Samples were taken at the depth of 1-20 cm in soils under agricultural land use, 1-40 cm in horticultural land use and 1-60 cm in forest areas (Pennock, Yates and Braidek, 2008). First a strip of soil of 1 cm contaminated with litter and other unwanted things was scraped away from the top at each sub-sample location and then a small pit was dug and sample was taken by cutting a vertical slice with the spade. The soil sub-samples were collected on a clean sheet of cloth/polythene and mixed thoroughly. Samples weighing 500 g worth to be sent to the lab for analysis were prepared by repeating the processes of spreading the soil on the sheet, dividing it into quarters, rejecting the opposite quarters and remixing the rest of the soil. The samples were finally put into respective clean polythene bags, kept tightly and labeled clearly and properly for identification (as shown in annexure). The details of the samples were entered on the information sheet/field dairy.

3.2.6. Preparation of the Soil Samples for Analysis

After the process of collection of the samples was complete, they were taken to the Residue and Quality Analysis Lab, SKUAST, Shalimar, Kashmir. The soil samples were reached within a day. So, for the preparation of soil samples was concerned, they were undergone through the processes of air drying under shade, homogenizing, crushing, grinding and sieving. When the soil samples were reached to the lab, they were put in well labeled paper bags and were air dried under shade for open drying under sunlight vaporizes the volatile elements like iodine. Drying at high temperature inside a room may also lead to certain undesirable changes in the physico-chemical characteristics of the samples (Hlaway, *et al*., 2004; Gelderman and Mallarino, 1998; Motsara and Roy, 2008). Air-dried samples were crushed and ground with a wooden pestle and mortar and passed through a 10 mesh (<2 mm) sieve (Boulding, 1994). The process was repeated till whole sample was not sieved and sifted except concretions (Motsara and Roy, 2008). Finally, the sieved sample was again ground in an agate mortar to take <63 µm particle size and passed through 60 mesh screen (Boulding, 1994). The soil samples were then digested by following APHA (1998) guidelines.

3.2.7. Collection and Preservation of the Water Samples

The water samples were collected from the selected sample sites in cleaned plastic bottles of 500 mL capacity. Great care was taken to avoid contamination of the samples. Before taking the samples, the bottles were thoroughly washed with nitric acid (1%), distilled water and water to be sampled. The pH of the water samples was determined on-site by a digital pH meter since the maximum holding time for pH of water samples is only 15 minutes. So far the collection of sample from a tap is concerned, the tap was opened fully to allow water to run for a few minutes to clear the service line and then the sample was taken. Leaking taps were avoided. To take sample direct from a source i.e., a spring or a stream, care was taken so that the sample should be representative of the water supplied to the consumers. Hence, a sample was neither taken too far from the point of draw-off nor too close. The sampling bottles were not filled up to brim and 2-3 cm space was left free for shaking and adding preservatives (BIS, 2003). To preserve the collected water samples, nitric acid (1.5 mL to pH <2) was added to the samples and the caps were tightly replaced (ADEQ, 2012). The samples were properly labeled (as shown in annexure) and returned to the lab within 6 hours for preservation (keeping in cool condition at 4^0C) and analysis. After acidifying the sample was stored in a refrigerator at approximately 4°C to prevent change in volume due to evaporation. Under these conditions, samples with metal concentrations of several milligrams per liter are stable for up to 6 months (APHA, 1998). The water samples were then digested by following APHA (1998) guidelines.

3.2.8. Analysis of the Soil and Water Samples for pH and OM

3. 2.8.1. Soil pH

Soil pH is a measure of hydrogen ion activity in the soil solution. Electrometric method was adopted to determine the pH of the soil samples (Watson and Brown, 1998).

3. 2.8.2. Water pH

The pH of water samples was determined by means of a digital pH meter.

3. 2.8.3. Organic Carbon in Soil

Walkley and Black (1934) titration method was followed for the estimation of organic carbon in soils which states as:

$$\frac{10(S-T)\times 0.003}{S}\times\frac{100}{Wt.of\ soil}$$

Where:

S = millimetres of $FeSO_4$ solution required for blank

T = millimetres of $FeSO_4$ solution required for soil sample

0.003 = weight of C (1000mL 0.1667M $K_2Cr_2O_7$ = 3 g C. Thus, 1 mL 0.1667 M $K_2Cr_2O_7$ = 0.003 g C)

The organic C is converted into OM as:

Percent value of organic carbon obtained × 100/77×1.724

3.2.9. Analysis of the Soil and Water Samples for Cu, Zn and I

Samples digested were directly analyzed on the Atomic Absorption Spectrophotometer against reagent blank elements like copper, zinc and iodine and were detected using respective wavelength and lamps. Trace elements were detected using Flame Atomic Absorption Spectroscopy (Jackson, 1967; Baker and Amacher, 1982). The trace elements were calculated as:

Content of trace element in the sample (mg kg^{-1}) = C µg/mL × 2 (dilution factor)

Where, dilution factor = 2.0 (sample taken = 10.0 g and DTPA used = 20 mL) Absorbance reading on AAS of the extract being estimated for a particular element=X

Concentration of micronutrient as read from the standard curve for the given absorbance (X) = C µg/mL.

3.2.10. Framing and Designing of the Household Survey Schedule

A comprehensive household survey schedule was framed and designed after reviewing a huge volume of literature related to the study. The schedule was attempted to cover up almost all the socio-economic components of the population of the sampling villages. It included the aspects of demographic structure, economic status, type of food items taken, dependence on local foods, trace element related disorders, methods of cooking, types of utensils used for cooking, fertilizers used, and the like as is clear from the schedule format given in appendix.

3.2.11. Socio-Economic Survey and Data Tabulation (Generation of Master Sheet)

When the process of designing the survey schedule was over, the actual collection of data was started. This was a type of door-to-door survey (as shown in annexure). Since this process relates with the human population and their lifestyle, the data was collected with an ethnographic approach. The survey was done randomly in only those villages from which soil and water samples were taken earlier and only about 10% of households were surveyed. After that, the collected raw data was processed and a master sheet was generated in which data about different parameters and components of the study were shown separately.

3.2.12. Statistical Analysis

3.2.12.1. Statistical Tests

Important statistical tests (one-way ANOVA, post-hoc tests and independent-samples T-Test) were used to test and analyze the data. These tests were employed to see the validity of the results highlighting whether the statistic score (mean) differences and variations are statistically significant or not across the altitudinal zones and within them and among particular altitudinal zones. For the present study, the level of significance or the alpha (α) level which is the area of rejection was set at 0.05 (i.e., 5% of the sampling distribution). In two-tailed tests like independent samples T-Test, these 5% were partitioned to both the sides of the distribution with each tail (or rejection region) containing 2.5% of the distribution. Before analyzing the data using these tests, it was checked to make sure that the data could actually be analyzed. So, the data was passed through six assumptions that are required for these tests to give a valid result (https;//statistics.laerd.com/spss-tutorials/one-way-anova-using-spss-statistics.php; https;//statistics.laerd.com/spss-tutorials/independent-t-test-using-spss-statistics.php).

The data was checked for the above mentioned assumptions for both the one-way ANOVA and Independent samples t-Test. The first three assumptions were met by data and no statistical pre-testing was required.

Then the data was checked for identification of outliers and minor outliers were found in data about concentration of zinc in the drinking water sources. The outliers were removed by using robust estimation methods. Windsorized mean was used to deal with the problem of outliers in which the highest and lowest observations are temporarily censored and replaced with adjacent values from the remaining data (Osborne and Amy, 2004).

After dealing with the outliers, the data was tested for normality and homogeneity of the variances by using SPSS for both the tests since these are the two most important prerequisites of parametric tests. SPSS was employed to improve the objectivity in the analysis. For assessment of normality of data, the Shapiro-Wilk's method of testing normality was used because it is more appropriate for small sample sizes (<50 samples). Under this test, the data is said to be normal, when the value of significance (p-value) is greater than the level of significance (i.e., 0.05). (https;//statistics. laerd.com /spss-tutorials/testing-for-normality-using-spss-statistics.php). It was found that all the data sets were normally distributed in both the cases.

The homogeneity of variances was checked by using Levene's test of Equality of Variances in SPSS. The variances are said to be equal or homogenous when the significance value (p-value) is greater than the level of significance (i.e., 0.05). However, if $p<0.05$, the variances are said to be unequal and the assumption is violated (https;//statistics.laerd.com/statistical-guides/independent-t-test-statistical-guide.php). If this assumption is violated, the alternative statistical tests such as Welch ANOVA, Games-Howell post-hoc test and Welch t-test are used instead of one-way ANOVA, Tukey post-hoc test and Independent samples-t-Test respectively since the former tests are robust to the violations in the assumption of homogeneity of variances and do rely on the assumption of unequal variances (https;//statistics.laerd.com/spss-tutorials/one-way-anova-using-spss-statistics.php; https;//statistics.laerd.com/spss-tutorials/one-way-anova-using-spss-statistics-2.php; https;//statistics.laerd.com/statistical-guides/independent-t-test-statistical-guide.php).

Once, the process of checking and finding the data as per the six assumptions, actual statistical tests were employed using SPSS.

3.2.12.2. Computation of Composite Score

The standard score was computed by following a standard methodology to find out the essential trace element deficiency disease risk zones and classify the sample villages into different disease risk zones. The two main steps involved in the computation of z-score or composite score are the removal of biasness of scale and assignment of weights to the variables. The biasness of scale was removed through the method of standardization (Mahmood, 1986). The values of 1, 2 and 3 were assigned as weights to the variables of dependence on non-local food products (%), concentration of essential trace elements in soils (I, Cu, Zn) and concentration of essential trace elements in drinking waters (I, Cu, Zn) respectively. The composite score was calculated as

$$\sum_{i=1}^{n} (\mathbf{SViSj} \times \mathbf{WiSj})$$

Where, SV_iS_j= Standardized Variables from 1 to 7 at sample site j (j =1 to 23) and

W_iS_j = Weights given to Standardized variables from 1 to 7 at sample site j.

The following formula was used to perform standardization of raw scores or variables:

$$SV_iS_j = X_i - \mu_i / \sigma_i$$

Where, SV_iS_j= Standardized Variables from 1 to 7 at sample site j (j =1 to 23) and

X_i = Raw scores or variables (i= 1 to 7)

μ_i = Mean of the values of the each variable and

σ_i = Standard Deviation of the values of the each variable

In the representation part, the data was presented in the form of graphs and figures to highlight the relation among the variables across the altitudes.

CHAPTER-4

TRACE ELEMENTS AND HUMAN HEALTH: CONCEPTUAL BACKGROUND

4.1. TRACE ELEMENTS: CONCEPTUAL BACKGROUND

Trace elements generally refer to elements that occur in natural and modified or perturbed environments in small amounts and that, when present in imbalanced (excessive or deficient) bioavailable concentrations, are harmful to the living organisms especially human beings.

Depending on the field of study, the term trace element is loosely used in literature and is known by different names as potentially toxic elements, heavy metals, micronutrients, and minor elements. The term "potentially toxic elements" is a recent term, meant to illustrate that while some elements are toxic to humans and plants, not all elements are toxic at all concentrations. In fact, micronutrients (e.g., Cu, I, Zn,) are necessary for life in small amounts (Alloway, 1995). Heavy metals are elements having densities greater than 5.0 g cm^{-3} and denote metals and metalloids that are associated with pollution and toxicity but also include essential elements. Over the past two decades, the term 'heavy metals' has been widely used… and related to chemical hazards. It is often used as a group name for metals and semimetals (metalloids) that have been associated with contamination and potential toxicity or eco-toxicity. This term is based on various criteria (i.e., atomic weight, atomic number, density, chemical properties etc.). Chemists define trace elements, or transition metals, as those elements which fall in the center of the periodic table (between Group IIA and IIIA) and exhibit partial d-orbital filling. Other chemical definitions are based on density (greater than 5 g cm^{-3}), atomic weight (greater than that of sodium), and metallic properties. Soil fertility experts define trace elements as those elements that are essential to plant growth in small amounts, but toxic to plants at higher concentrations. Toxicologists consider trace elements those elements distributed into the environment by industrial processes that are detrimental to human health or the environment. This definition is not based on abundance in the environment, or density or metallic properties, but solely on the adverse effects of the element in the environment. Earth scientists define trace elements as those elements in rocks other than the eight most abundant rock-forming elements (i.e., O, Si, Al, Fe, Ca, Na, K, and Mg) found in the Earth's crust or natural environment. Geochemists use the term "trace elements" for the elements present in the earth's crust in concentrations less than 0.1% (<1000 mg kg^{-1}). In biochemical and biomedical research, trace elements are believed to be those elements that are ordinarily present in plant or animal including human beings tissues in concentrations less than 0.01% (<100 mg kg^{-1}) of the organism's dry weight. In food and nutrition science, a trace element may be defined as an element that is of common occurrence but whose concentration rarely exceeds 20 ppm in the foodstuffs consumed. It is to be noted here that some of the nutritive trace elements (e.g., Mn, Zn) may often exceed this concentration (Adriano, 2001).

4.1.1. Goldschmidt's Classification

It seems appropriate to briefly highlight the affinities and tendencies of trace elements in the natural phases of environment through Goldschmidt's classification of elements of the periodic table. Most of the elements of periodic table fall into the ambit of trace elements and so, this is a good place to reflect on the geochemical characteristics of the elements. Goldschmidt recognized four broad categories of elements: atmophile, lithophile, chalcophile, and siderophile (White, 2012) (Table 4.1). Atmophile elements are generally extremely volatile (i.e., they form gases or liquids at the surface of the Earth) and are concentrated in the atmosphere and hydrosphere. Lithophile, siderophile and chalcophile refer to the tendency of the element to partition into a silicate, metal, or sulfide liquid respectively. Lithophile elements are those showing an affinity and tendency for silicate phases and are concentrated in the silicate portion (crust and mantle) of the earth. Siderophile elements have an affinity for a metallic liquid phase. They are depleted in the silicate portion of the earth and presumably concentrated in the core. Chalcophile elements have an affinity for a sulfide liquid phase. They are also exhausted in the silicate earth and may be concentrated in the core. Many sulfide ore deposits originated from aqueous fluids rather than sulfide liquid. A chalcophile element need not essentially be concentrated in such deposits. As it works out, however, they generally are. Most elements that are siderophile are usually also somewhat chalcophile and vice versa.

The trace elements of copper and zinc behave as chalcophile while as iodine is lithophile in nature. Sometimes zinc also shows lithophile character.

Table 4.1: Goldschmidt's Classification of the Elements

Atmophile	Chalcophile	Lithophile	Siderophile
H, N, O	**Cu**, Ag, Be, Mg, Ca, Sr, Ba, Ga, In, Tl, Ge, Sn, Pb, As, Sb, Bi, S, Se, Te, Fe, Mo, Os, Ru, Rh, Pd	Li, Na, K, Rb, Cs, He, Ne, Ar, Kr, Xe, B, Al, Sc, Y, Si, Ti, Zr, Hf, Th, P, V, Nb, Ta, O, Cr, U, H, F, Cl, Br, **I**, Fe, Mn, **Zn**, Ga	Fe[1], Co[1], Ni[1], Ru, Rh, Pd, Zn, Cd, Hg, Os, Ir, Pt, Au, Re[2], Mo[2], Ge[1], Sn[1], W[3], C[3], Cu[1], Ga[1], As[2], Sb[2]

1=Chalcophile and lithophile in the earth's crust
2=Chalcophile in the earth's crust
3=Lithophile in the earth's crust

Source: White, 2012

4.1.2. Trace Elements in Soils

Trace elements in soils are derived from the parent materials through the processes of weathering and may be increased substantially by man's industrial and other activities (Kabata-Pendias and Pendias, 2001). There are generally higher quantities of trace elements in igneous and metamorphic rocks than in sedimentary rocks. They account for 95% of the earth's crust and remaining 5% is contributed by sedimentary rocks. Of the sedimentary rocks 80% are shales, 15% sandstones and 5% limestones. Sedimentary rocks are the most important soil parent material since they overlie most igneous formations, and account for 75% of the outcrops at the earth's surface (Wedepohl, 1991).

Trace elements in soils by and large tend to be immobile. Some transfer of trace elements in the A horizon occurs with plant uptake and nutrient cycling. However, trace elements in soils are generally insoluble and exhibit strong adsorption.

Soil is the main source of trace elements for plants as micronutrients. It is also a direct source of these elements to humans due to soil ingestion affected by "pica-soil", geophagia, dust inhalation, and absorption through skin. The soil-plant transfer of trace elements is a part of chemical element cycling in nature. It is a very complex process governed by several factors, both natural and affected by humans.

Soils contain trace elements of various origins: (i) lithogenic – inherited from the lithosphere (parent material), (ii) pedogenic – from lithogenic sources modified due to soil-forming processes, and (iii) anthropogenic – elements deposited onto and/or into soils as results of human's activities especially agriculture, mining, industry and sewage disposal. Soil processes and anthropogenic factors control the behavior of all these elements (Table 4.2). It has been assumed that the behavior of trace elements in soils and in result their phytoavailability differ according to their origin. Several recent reports have shown that regardless of the forms of the anthropogenic trace metals, their availability to plants is significantly higher than those of natural origin (Kabata-Pendias and Pendias, 2001).

Table 4.2: Influence of Origin of Trace Elements on their Behavior in Soil

Origin	Association	Phase	Form	Bioavailability
Lithogenic	Minerals or attached to minerals	Solid	Residual	Very slight
Pedogenic	CC, SOM, OX	Solid	Fixed by CM, SOM, OX	Slight
	Simple and complex ions	Aqueous	Free ions and non-ionic forms	Easy
Anthropogenic	Minerals, SOM, PS	Solid	Mainly exchangeable and chelated	Moderate and easy
Pedogenic and anthropogenic	Simple and complexed ions	Aqueous	Free ions and non-ionic forms	Easy

Source: Kabata-Pendias and Pendias, 2001

Note: CC = clay content, SOM= soil organic matter, OX= oxides and hydroxides, PS= particle surface

Weathering is the basic soil-forming process which involves a complex set of interactions between the elements of lithosphere, atmosphere, and hydrosphere that occur in the biosphere and are powered by solar energy. The behavior of elements during weathering and pedogenic processes are highly associated with their geochemical properties, which are base for the geochemical classification (Table 4.3). The majority of elements reveal lithophilic character, which indicates a tendency to form oxygen compounds, as well as silicates, carbonates, phosphates, and sulfates.

Table 4.3: Geochemical Classification of some Trace Elements

Siderophile	Chalcophile	Lithophile
Mo, Co, Au, Os, Ni, As, Ge, Sn, Ru,	Ru, Cu, Ag, Zn, Cd, Hg, Ga, In, Tl, Pb, As, Sb,	Li, Rb, Cs, Be. Ba, Sr, Ra, Zr, Hf, V, Ta, Cr, Mo, Mn, Zn,B, Lanthanides, Actinides, Halogens

Source: Kabata-Pendias and Mukherjee, 2007.

Clay minerals, the main products of weathering and soil development, are due to water-rock interaction processes. Two types of compounds released by organic matter or organisms are believed to be particularly involved in weathering processes: carbonic acid, formed from the CO_2 released during decay of organic matter, and organic chelates.

Pedogenic processes cannot be easily distinguished from weathering processes as they take place simultaneously and at the same sites; most often they are closely interrelated. The principal types of these processes include: (i) podzolization, (ii) alkalization, (iii) aluminization, (iv) laterization, (v) salinization, and (vi) hydromorphic processes. All these processes control the distribution and behavior of trace elements in distinct layers of soil profiles that are related to sorption and desorption and to the formation of various species of elements.

The main soil parameters governing these processes are: (i) pH and Eh values, (ii) amount and mineral composition of the fine granulometric fraction (<0.2 mm), (iii) amount and kind of organic matter, (iv) oxides and hydroxides of Fe, Mn and Al, and (v) microorganisms.

Smith and Huyck (1999) described mobility of metal ions under different environmental settings. Although it is rather difficult to predict trace element mobility in soils and other terrestrial ecosystems, the authors referred to the capacity of an element to move with fluids after dissolution in surficial environments. The following conditions and behavior of trace elements were distinguished:

- Oxidizing and acid, pH <3: *(a)* very mobile – Cd, Co, Cu, Ni, and Zn, *(b)* mobile – Hg, Mn, Re, and V, and *(c)* somewhat mobile and scarcely mobile – all other metals
- Oxidizing in the absence of abundant Fe-rich particles, pH >5: *(a)* very mobile – Cd and Zn, *(b)* mobile – Mo, Re, Se, Sr, Te, and V, and *(c)* somewhat mobile and scarcely mobile – all other metals
- Oxidizing with abundant Fe-rich particulates, pH >5: *(a)* very mobile – none, *(b)* mobile – Cd and Zn, and *(c)* somewhat mobile and scarcely mobile – all other metals

- Reducing in the absence of hydrogen sulfide, pH >5: *(a)* very mobile – none, *(b)* mobile – Cd, Cu, Fe, Mn, Pb, Sr, and Zn, and *(c)* somewhat mobile and scarcely mobile – all other metals
- Reducing with hydrogen sulfide, pH >5: *(a)* very mobile – none, *(b)* mobile – Mn and Sr, and *(c)* scarcely mobile to immobile – all other metals

Other soil minerals such as, carbonates, phosphates, sulfides, sulfates and chlorides may have important influences on the distribution and behavior of trace elements in soils developed under specific geological and climatic conditions (Kabata-Pendias and Sadurski, 2004).

The effects of soil characteristics on trace element concentrations in soils have been studied by many soil scientists. In brief, seven factors determine the fate of trace elements in soil: soil pH, cation exchange capacity (CEC), anion exchange capacity (AEC), organic matter content, clay content and type, oxide content and type, and redox potential. Trace element sorption depends on pH and whether the element occurs in anionic or cationic form. Cation sorption increases with pH showing a steep increase within a small pH range, which is known as the adsorption edge. Sorption of anions shows a maximum when the pH is equal to the pKa of the corresponding acid. This phenomenon is known as the adsorption envelope. A high CEC or AEC allows a soil to hold more cations or anions, respectively, than a soil with a low CEC or AEC. The exchange capacity of a soil is related to other soil properties, such as organic matter, clay, and oxide content. Soil organic matter retains elements both through its exchange capacity and through specific sorption, especially for elements such as Cu, Co, Mn, and B. A soil high in clay has more surface area for elements to adsorb and a higher CEC than a soil low in clay. Also, 2:1 clays usually have a higher CEC than 1:1 clays. Redox potential of a soil can change the solubility of an element. When a soil is reduced, some elements such as Fe, Cd, Ni, and Pb can form insoluble sulfide precipitates.

Soil solution: Transfer of trace elements between soil phases should be considered as the main process controlling their behavior and bioavailability. The aqueous phase of the soil (soil solution) is composed of water with a colloidal suspension, free and/or complexed, and dissolved substances of various compounds, including bio-inorganic complexes. Concentrations of trace elements in soil solution are closely correlated with their mobility and availability. In this phase, the minerals are highly bioavailable.

4.1.3. Trace Elements in Water

Freshwater: Water plays essential functions in geochemical and biochemical processes. It is also a main carrier for all chemical elements; its amount and chemical composition control element cycling in water-air-soil systems. Thus, water is probably the most studied medium that governs the forms of trace elements of which Cr, Se, Cu, As, Pb, Cd, and Hg have been studied the most frequently (Das, *et al*., 2001 cited in Kabata-Pendias and Mukherjee, 2007).

The main ions dissolved in waters are: Na^+, K^+, Mg^+, Ca^+, Cl^-, SO_4^{2-}, HCO_3^-, and these also occur as different species and variable concentrations adsorbed by inorganic and organic colloidal particles. So-called secondary elements (C, N, P, S, and Si) as well as trace elements occur in all water systems, in highly variable concentrations, depending on several factors of which pollution plays a significant role. Water pollution by trace elements is an important factor in both geochemical cycling of trace elements and in environmental health. The water cycle of trace elements plays a significant role in each aquatic and terrestrial ecosystem. Especially cycling of trace metals in the oceans and their role in the photosynthetic fixation of carbon by phytoplankton is of great importance.

Most trace elements especially trace metals; do not remain in soluble forms in waters, for a longer period. They are present mainly as suspended colloids or are fixed by organic and mineral substances. On the other hand, easily volatile elements such as Br and I can reach higher concentrations in surface waters, from which they can easily, vaporize under favorable climatic conditions. Trace element speciation in water control their behavior and toxicological risk. The bioavailability of trace elements to both unicellular and higher organisms is the result of complex reactions between the ligands present in the aqueous medium and those of living cells. Practically, all fractions of trace elements, truly dissolved and associated with suspended particulate matter, may be bioavailable to aquatic organisms.

Ground waters: About 99% of the world's fresh, available water is groundwater that is a basic source of the domestic, industrial, and agricultural water supply (Bhattacharya and Mukherjee, 2002). The transfer of trace elements depends on several properties of the soil media as well as on the geochemical properties of an element. Thus, elements that predominate in soils in easily mobile forms are of higher hazard than those that are relatively stable in prevalent soil conditions.

The chemical quality of groundwater is of special importance, as it is a source of both drinking and irrigation waters and therefore, has a significant impact on trace element transfer into the food chain.

Drinking waters: Concentration of trace elements in drinking water is of special concern in relation to health. Several ecological studies have indicated an influence of the quality of drinking water on some diseases. Liu *et al*. (2000, cited in Kabata-Pendias and Mukherjee, 2007) have reported significantly increased levels of Ti, V, Fe, Cu and Sr in drinking water collected from areas with high incidence of gastric carcinoma.

The quality of drinking water is very important since it is consumed every day during the whole lifetime. Momot and Synzynys (2005) have calculated daily intake of several metals by inhabitants of Obninsk (Middle Russia) and assessed that it may be a risk of oncological diseases to 4 of 100 persons and of non-oncological diseases to 1 of 1, 000 persons. The daily doses of metals to this population are as follows (in µg kg^{-1} BW): Ag-<1.0; Al-4.01; As-1.28; B-2.57; Be-0.04; Cd-1.03; Cr-2.1; Hg-0.17; Pb-0.43; and Zn-0.17.

4.1.4. Trace Elements in Biosphere

The biosphere is the natural environment of living organisms and is the complex biological epidermis of the Earth existing at the interface of the three major realms of the natural environment i.e., lithosphere, hydrosphere and atmosphere, characterized by continuous cycling of chemical elements and flow of energy. There is a homeostatic interrelationship between the nonliving media (abiotic compartments) and the living organisms (biotic compartments). However, a significant part of the natural environment has already been considerably modified by humans, and these processes will continue.

Most of the chemical elements for life including humans on the land are supplied mainly from the soil (Kabata-Pendias and Mukherjee, 2007) and secondly from water. The concentration of trace elements in different phases of natural environment creates several problems for plants, animals and humans associated either with their deficiency or with excess. Thus, questions of how and how much of an element is taken up by organisms and what is its concentration in the living systems have been hot topics of research in recent decades. Usually, the quantitative differences between essential or required amounts and excesses/deficiencies of trace elements are very small. The bioavailability of these elements is variable and is controlled by specific properties of abiotic and biotic media as well as by physico-chemical properties of a given element.

The biochemical functions of essential trace elements have been unraveled by many great scientists. Essential trace elements are known to have a biological role, often as cofactors or part of cofactor in enzymes and as structural elements in proteins. Some of them also are used in several processes of electron transfer. Non-essential elements seem to be involved in vital processes but their biochemical functions are not yet understood. The essentiality of other trace elements, possible at very minor concentrations, may be revealed in the future. Most of trace elements that are essential to humans are also essential to plants. Unfortunately, contents of most elements that may be harmful to humans and animals are not toxic to plants. This has created an amplified transfer of some elements in the food chain.

The survival of mankind is somehow dependent on foods of different varieties. Lack of food as well as bad quality of food has created throughout the centuries serious health problems for people. Nowadays it has been found that more than 3 billion people worldwide suffer from either deficiency or toxicity of some trace elements.

It seems pertinent to remind Paracelsus' (1538) statement cited in Kabata-Pendias and Mukherjee, 2007:

"All substances are poisonous, there are none which is not a poison; the right dose is what differentiates a poison from a remedy"**.**

4.1.5. Trace Elements in Human Beings

Since the father of human beings, Aadam (AS), was created from clay and all human beings take foods (including air and water) derived from the earth system, they like other living organisms have developed their internal biochemistry in close connection to the composition of the natural environment. Humans, as well as all mammals, unlike prokaryotes and other lower organisms, are not able to adapt easily to any change in the chemical composition of their surroundings. Variations in trace element concentrations are of vital importance. The homeostatic balance of chemical elements in any organism is the basic requirement of good health. Ionic relationships within any organism are very fragile and governed by several factors. Their balance is controlled by factors such as bioavailability of an element, capability of tissues or organs to accumulate and excrete an element and by interactions among elements that might vary from antagonistic to synergistic depending mainly on their quantitative ratio.

Trace elements, both essential and non-essential, play fundamental roles in the normal development and health of humans. They commonly play the functions of metallo-enzymes. The elements that are essential for the activity of physiologically important enzymes and function as catalysts are Cu, Zn, and Fe (Kleczkowski *et al*., 2004 cited in Kabata-Pendias and Mukherjee, 2007).

Geochemical anomalies of the bedrock, variable soil properties, agricultural practices, and anthropogenic inputs influence the trace element contents of food crops and other plants resulting in a dietary intake of trace elements. Diseases and/or impaired metabolism, attributable to trace element deficiency or excess, are sometimes not easy to assess, especially at early stages of development. Moreover, effects of their imbalanced supply may be quite variable (Table 4.4).

Table 4.4: Consequences of Deficiency and Excess of Essential Trace Elements

Element	**Deficiency**	**Excess**
Iodine (I)	Goiter, cretinism, decreased fertility rate increased stillbirths, spontaneous abortion rates, increased perinatal and infant mortality	Hyperthyroidism {rapid heart rate, trembling, excessive sweating, lack of sleep, and loss of weight and strength}
Copper (Cu)	Anemia, bone fractures {osteoporosis, osteopeneisis}, hypopigmentation, prematurity growth retardation (children), fertility, hair and weight loss, menke's disease	Wilson's disease, vomiting, diarrhea, hemolytic anemia, renal & liver damage
Zinc (Zn)	Anorexia, anemia, impaired keratosis, teratogenic effects, alopecia, dermatitis, growth retardation, appetite loss, impaired wound healing and skin lesions, impaired taste/smell, diabetes	Nausea, vomiting, fever/diarrhea, epigastric pain, anemia, fatigue, dehydration, tissue lesions
Selenium (Se)	Cardiac myopathy, asteoarthropathy,	Selenosis, liver and kidney damage, cancer, fetal toxicity
Chromium (Cr)	Defective glucose metabolism, hyperlipidemia	Lesions in skin, lung cancer
Molybdenum (Mo)	Defects in keratosis, growth retardation	Molybdenosis, defect in Cu metabolism, diarrhea

Source: Kabata-Pendias and Mukherjee, 2007

Iodine deficiency occurs commonly in regions with light sandy soils developed from young geologic formations. It is not likely to occur in close-to-sea areas.

Contents of trace elements in the human body vary greatly, and are controlled by several external (local environment and foods grown) and internal (habits and diseases) factors.

Exposure sources: The general population is exposed to trace elements mainly by ingestion of drinking water and food and by inhalation of air. Adults inhale daily approximately 20 m^3 of air and intake about (above) 2 L of water. Human beings take trace elements from various sources by three absorption pathways:

- Gastrointestinal tract, from: food, water, drugs, soil, and aerosols
- Respiratory tract, from: aerosols, and gases
- Skin, from: soil, water, aerosols, gases, and others

The food chain is considered the main tract for transfer of trace elements to humans. There are several possible routes of their (TE) transfer from soil to human via food chain:

- Soil→plant→animal→human
- Soil→plant→human
- Soil→animal→human
- Soil→microbiota, mezobiota→human
- Soil→airborne dust→animal, human
- Soil-geophagia→human
- Soil→groundwater→drinking water→animal, human
- Soil/sediment→surface water→aquatic biota→human

A special source of some trace metals is associated with various orthopedic and stomatological metallic implants. Various alloys are used for orthopedic surgery. The most commonly are the alloys of Co, Cr, Mo, Ni and W. Metals are released into body tissues, due to the corrosion (in some cases due to the abrasion) of alloys

Trace element intake due to soil ingestion both involuntary and deliberate may be significant especially for children. Ingested mean amounts of some metals by children, 1–4 years of age, were as follows (in mg d^{-1}): Al-136; Ti-208; V-148; Zr-113; and Y-97 (Calabrese and Stanek cited in Abrahams, 2005). Significantly, however, the most often unrecognized sources of ingested metals are those released from kitchen utensils. It has been reported that cookware, especially enamel and stainless steel, may be a source of Cr, Ni, Zn, and Fe in popular soups.

The appreciation of the recommended dietary allowance (RDA) of essential trace elements is very important for the human health. It refers to the average daily dietary intake level that is sufficient to meet the nutrient requirement of nearly all (97-98 percent) health individuals in a particular life stage and gender group (ICMR, 2010). A group of experts of ICMR modified RDA of Indians taking into consideration the guidelines given by FAO/WHO. The table 4.5 gives the RDA for Indians of three important trace elements as:

Table 4.5: Recommended Dietary Allowances of I, Cu and Zn for Indians

Trace Element	Group	RDA
Iodine	Infants and Children (up to 5 years)	90 µg d^{-1}
	School Children (6-11 years)	120 µg d^{-1}
	Adolescents and Adults	150 µg d^{-1}
	Pregnant/Lactating Women	200 µg d^{-1}
Copper	Adults	1.35 mg d^{-1}
Zinc	Adult Man and Lactating/Pregnant Woman	12 mg d^{-1}
	Adult Woman	10 mg d^{-1}
	Children (1-9 years)	5-8 mg d^{-1}
	Boys and Girls (10-17 years)	9-12 mg d^{-1}

Source: ICMR, 2010.

4.2. HUMAN HEALTH: CONCEPT

Human health is a very complex topic to be dealt with. Many scholars have defined it differently. Herein, only the definition of human health is given that has been adopted by WHO in its World Health Assembly held in 1948. According to W.H.O., "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity". It is a very comprehensive definition that covers two primary aspects of health: i) physical health and ii) mental health. It also takes into account social well being of the people wherein different socio-economic, cultural and religious factors exercise their role on human health.

Physical fitness is achieved through proper nutrition in the daily diet and regular exercise that is determined by geo-environmental factors and socio-cultural and economic set-up of the society/individual. Mental stability depends on psychological well-being that is partially dependent on nutrition and socio-religious factors. Likewise, social fitness and stability is conditioned by the ability to operate comfortably within the expectations of the society the individual lives. Though these health aspects are explained separately, but in practical they are highly interlinked with one another and change in one aspect of human health leads to change in another aspects as well.

Human health is conditioned by a multitude of factors involving geo-physical, social, cultural, religious and economic. Human beings are so complex that they have interdependence on all the above mentioned factors. The soil, water and air quality and quantity, the climatic phenomena, the socio-cultural set-up and economic standard, all determine directly or indirectly the health of people settled at a place.

CHAPTER-5

RESULTS AND DISCUSSION

5.1. CONCENTRATION OF ESSENTIAL TRACE ELEMENTS

The trace elements primarily occur in rocks wherefrom they are transferred to the soil and water systems through many natural and anthropogenic processes. Since, the soil is the base of the food chain and water is the elixir of life, they are of very high importance.

The iodine, copper and zinc contents in the soils vary from one soil type to another and with the altitude. It has been revealed that the concentration these elements vary especially with the variability in OM, clay content and pH in the soils. The OM causes strong adsorption of iodine in solid phase of soil and hence increases its content in soil but reduces its mobility and bioavailability. The low pH (acidic medium) contribute in the leaching, desorption, dissolution and volatilization of iodine in solid and fluid media of soil. Besides, the other soil characteristics such as texture, stoniness, slope, drainage, presence of calcites and degree of erosion influence the behavior and distribution of iodine in the soil. The soils underlain by carbonate rocks and having high clay content also contain relatively elevated iodine contents. Researchers have found that only about 25% of soil iodine is in liquid phase and hence bioavailable to plants and free to move to surface and ground waters leading to human exposure to iodine. Researchers have found that OM and clay fraction exercise so strong influence that only about 1% copper of the total in soil remains in soil solution. Generally, soils having less than 10 mg kg^{-1} total copper content are referred as copper deficient (Kabata-Pendias and Mukherjee, 2007).

5.1.1. Concentration of Essential Trace Elements in Lower Foot Hill Settlements-1 (LFHs-1)

The average iodine concentration, pH and OM in the soils of LFHs-1 are 1.26mg kg^{-1}, 6.83 and 3.30% respectively. The total iodine content, pH and OM in sample sites varies from 0.95-1.62 mg kg^{-1}, 6.42-7.51 and 1.34-5.17%. The lowest value of iodine content (0.95 mg kg^{-1}) was found in soil type-81 at SS4-KUL and highest (1.62 mg kg^{-1}) in soil type-58 at SS10-BAR. This is because of low OM (1.34%) and relatively acidic pH (6.70) in the former than the latter which contains relatively high OM (4.88%) and neutral pH (7.02) (Table 5.1.1). Out of the 11 soil sample sites in LFHs-

1, 5 sample sites (SS3-KUL, SS6-SHO, SS8-BUD, SS9-BUD and SS10-BAR) recorded iodine concentration more than the average iodine concentration of 1.26 mg kg^{-1}. The other sample sites such SS1-ANG, SS2-ANG, SS4-KUL, SS5-SHO, SS7-PUL and SS11-BAR revealed iodine concentration less than average values (Table 5.1.1).

The mean copper content of 2.11 mg kg^{-1} was found in soils of LFHs-1. The total copper content at sample site level varied from 0.26-3.02 mg kg^{-1}. Five sample sites (SS2-ANG, SS3-KUL, SS6-SHO, SS9-BUD and SS10-BAR) out of 11 sample sites record copper concentration above than the mean copper content in the sub-zone (Table 5.1.1).

The zinc content, pH and OM in the soils of this sub-zone varied from 0.34-1.861 mg kg^{-1}, 6.42-7.51 and 1.34-5.17% respectively. The lowest value of zinc was found in soil type-81 at SS6-SHO due to low OM (2.06%) and below neutral pH (6.71) and other related soil features. While the highest value is exhibited by soil type-58 at SS3-KUL due to relatively high OM (4.00%) and alkaline pH (7.09) and other related soil features. Exactly, 5 sample sites (SS1-ANG, SS3-KUL, SS8-BUD, SS9-BUD and SS10-BAR) record higher zinc content than the average zinc concentration (1.130 mg kg^{-1}) in the soils of the sub-zone (Table 5.1.1).

Table 5.1.1: Concentration of Essential Trace Elements in Soils

Macro Regions	Micro Regions	Sample Sites	Soil Type	Conc. of Trace Elements (mg kg^{-1})			pH	Organic Matter (OM in %)
				Iodine	Copper	Zinc		
LOWER FOOT HILLS	LFHs-1 (1,800-2,100 m AMSL)	SS1-ANG	61	0.98	1.664	1.134	6.42	2.15
		SS2-ANG	106	1.00	2.270	0.798	6.51	3.76
		SS3-KUL	58	1.50	3.012	1.861	7.09	4.00
		SS4-KUL	81	0.95	1.901	0.670	6.70	1.34
		SS5-SHO	58	1.10	1.558	0.674	6.69	1.48
		SS6-SHO	81	1.45	2.396	0.340	6.71	2.06
		SS7-PUL	106	1.22	2.023	0.901	6.90	3.21
		SS8-BUD	105	1.42	0.260	1.710	7.51	5.17
		SS9-BUD	58	1.56	3.002	1.654	7.07	4.76
		SS10-BAR	58	1.62	3.021	1.560	7.02	4.88
		SS11-BAR	106	1.03	2.102	1.101	6.50	3.51
	Mean			**1.26**	**2.11**	**1.13**	**6.83**	**3.30**
	LFHs-2 (2,100-2,400 m AMSL)	SS12-ANG	61	1.23	1.558	1.332	6.28	3.76
		SS13-ANG	106	0.97	1.654	0.734	5.88	3.42
		SS14-KUL	58	1.55	3.043	1.962	7.15	4.44
		SS15-KUL	81	1.47	2.078	0.950	7.00	3.05
		SS16-SHO	58	1.37	1.684	1.582	6.52	5.24
		SS17-SHO	81	1.02	4.450	1.176	5.66	2.69
		SS18-BUD	105	1.36	2.396	0.500	6.89	3.02
		SS19-BUD	58	1.02	2.090	1.502	7.44	3.65
		SS20-BAR	58	1.65	3.956	1.750	6.99	5.07
		SS21-BAR	106	1.53	2.985	1.102	7.00	4.02
	Mean			**1.32**	**2.59**	**1.26**	**6.68**	**3.84**
Mean				**1.29**	**2.34**	**1.190**	**6.76**	**3.56**
UPPER FOOT HILLS	UFHs (2,400-3,000 m AMSL)	SS22-ANG	61	1.05	1.160	1.772	7.42	4.90
		SS23-ANG	106	1.34	0.930	0.570	6.56	1.34
		SS24-KUL	58	1.44	2.013	1.350	7.00	3.90
		SS25-KUL	81	0.90	1.801	1.270	6.70	2.91
		SS26-SHO	58	1.35	2.945	1.806	6.89	5.02
		SS27-SHO	81	1.29	1.974	1.131	6.56	2.53
		SS28-BUD	105	1.45	0.956	0.903	7.59	3.34
		SS29-BUD	58	1.00	2.780	1.302	7.05	3.70
		SS30-BAR	58	0.99	1.076	0.560	6.43	1.90
		SS31-BAR	106	1.55	3.342	0.903	7.24	4.45
	Mean			**1.24**	**1.90**	**1.157**	**6.94**	**3.40**
Mean				**1.27**	**2.20**	**1.179**	**6.82**	**3.51**

Source: Based on Sample Analysis carried out at RQA Lab, SKUAST-K, 2013

The average iodine content in drinking waters was found as 3.1 µg L^{-1}. The iodine content in the drinking water samples ranged from 2.2-4.3 µg L^{-1} and pH from 7.23-7.85. The lower iodine content was found in TSm drinking water source at SS8-BUD and higher value in TSm drinking water source at SS11-BAR (Table 5.1.2). Out of 11 water samples, 5 sample sites (SS1-ANG, SS6-SHO, SS7-PUL, SS9-BUD and SS11-BAR) showed higher iodine concentration than the mean iodine content (3.1 µg L^{-1}) of all the drinking water samples of the zone (Table 5.1.2).

The mean copper content and pH of water were recorded as 16.7 µg L^{-1} and 7.59 respectively. The copper content in drinking water irrespective of source ranged from 5.0-26.0 and pH ranged from 7.23-7.85. Out of 11 sample sites, 5 sample sites (SS1-ANG, SS6-ANG, SS8-BUD, SS10-BAR and SS11-BAR) revealed higher copper content than mean value for the sub-region of LFHs-1 (Table 5.1.2).

In the drinking water sources, the mean zinc content and pH were found as 43.1 µg L^{-1} and 7.59 respectively. The zinc content in drinking water at four sample sites (SS4-KUL, SS5-SHO, SS6-SHO, SS9-BUD and SS11-BAR) was found higher than its mean in the sub-zone. It varied from 16.0-90.0 µg L^{-1}. The pH showed a variation from 7.23-7.85 (Table 5.1.2).

Table 5.1.2: Concentration of Essential Trace Elements in Drinking Waters

Macro Regions	Micro Regions	Sample Sites	Water Source	Conc. of Trace Elements (µg L^{-1})			pH
				Iodine	Copper	Zinc	
LOWER FOOT HILLS	LFHs-1 (1,800-2,100 m AMSL)	SS1-ANG	TSg	3.4	18.0	16.0	7.53
		SS2-ANG	TSm	2.6	12.0	25.0	7.85
		SS3-KUL	Sg	3.0	15.0	30.0	7.35
		SS4-KUL	Sm	2.3	13.0	48.0	7.56
		SS5-SHO	TSg	2.4	5.0	90.0	7.73
		SS6-SHO	TSg	3.6	18.0	56.0	7.80
		SS7-PUL	Sg	3.5	15.0	35.0	7.25
		SS8-BUD	TSm	2.2	25.0	30.0	7.73
		SS9-BUD	TSm	4.1	14.0	45.0	7.23
		SS10-BAR	TSg	2.5	26.0	40.0	7.82
		SS11-BAR	TSm	4.3	23.0	59.0	7.62
	Mean			**3.1**	**16.7**	**43.1**	**7.59**
	LFHs-2 (2,100-2,400 m AMSL)	SS12-ANG	TSm	3.9	12.0	75.0	7.87
		SS13-ANG	TSg	4.2	12.0	217.0	7.54
		SS14-KUL	TSg	3.7	21.0	84.0	7.75
		SS15-KUL	TSg	3.5	22.0	120.0	7.45
		SS16-SHO	TSg	4.1	18.0	191.0	7.70
		SS17-SHO	TSm	4.4	18.0	19.0	7.80
		SS18-BUD	TSg	3.6	12.0	132.0	7.76
		SS19-BUD	TSg	3.2	17.0	110.0	7.53
		SS20-BAR	TSg	3.6	18.0	115.0	7.34
		SS21-BAR	TSm	3.0	20.0	124.0	7.61
	Mean			**3.7**	**17.0**	**115.8***	**7.64**
Mean				**3.39**	**16.9**	**79.1**	**7.61**
UPPER FOOT HILLS	UFHs (2,400-3,000 m AMSL)	SS22-ANG	Sg	2.7	16.0	93.0	7.75
		SS23-ANG	Sg	3.4	12.0	40.0	7.78
		SS24-KUL	Sg	2.3	14.0	22.0	7.72
		SS25-KUL	Sm	2.9	12.0	14.0	7.56
		SS26-SHO	Sg	3.1	13.0	37.0	7.36
		SS27-SHO	Sg	2.2	15.0	45.0	7.82
		SS28-BUD	Sm	3.5	18.0	19.0	7.45
		SS29-BUD	Sm	2.4	21.0	39.0	7.52
		SS30-BAR	Sm	2.8	19.0	96.0	7.71
		SS31-BAR	Sg	2.8	22.0	12.0	7.65
	Mean			**2.8**	**16.2**	**41.7**	**7.63**
Mean				**3.2**	**16.6**	**67.0**	**7.62**

Source: Based on Sample Analysis carried out at RQA Lab, SKUAST-K, 2013
*Windsorized mean in order to eliminate the impact of outliers
TSg=Tap fed by Spring, TSm=Tap fed by Stream, Sg=Spring and Sm=Stream

5.1.2. Concentration of Essential Trace Elements in Lower Foot Hill Settlements-2 (LFHs-2)

The average concentration of iodine in soils of LFHs-2 is higher (1.32 mg kg^{-1}) than the average iodine content in soils of LFHs-1. The reason behind the higher average iodine content retention in soils in this subzone can be ascribed to higher average OM (3.84%) in the soils of LFHs-2. The iodine content, pH and OM in the soils of sample sites varies from 0.97-1.65 mg kg^{-1}, 5.66-7.44 and 2.69-5.24%. The lowest value of iodine (0.97 mg kg^{-1}) was found in soil type-106 at SS13-ANG because of acidic (5.88) nature of the soil. The highest iodine content (1.65 mg kg^{-1}) was recorded in soil type-58 at SS20-BAR. The possible reasons for this are alkaline (6.99) nature and high OM (5.07%) in the soil (Table 5.1.1). Six (6) soil sample sites (SS14-KUL, SS15-KUL, SS16-SHO, SS18-BUD, SS20-BAR and SS21-BAR), out of 10 sample sites showed higher iodine concentration values than the average values (1.32 mg kg^{-1}) in the LFHs-2 (Table 5.1.1).

The average concentration of copper in soils of LFHs-2 is higher (2.59 mg kg^{-1}) than the average copper content in soils of LFHs-1. The reason behind the higher average copper content retention in soils in this subzone can be ascribed to higher average OM (3.84%) in the soils of LFHs-2. The copper content, pH and OM in the soils of sample sites varied from 1.56-4.45 mg kg^{-1}, 5.66-7.44 and 2.69-5.24%. The lowest value of copper (1.56 mg kg^{-1}) was found in soil type-61 at SS12-ANG. The lower value of copper concentration could be ascribed to skeletal nature, strong stoniness and severe erosional character of the soil. The highest copper content (4.45 mg kg^{-1}) was recorded in soil type-81 at SS17-SHO. Only 4 sample sites (SS14-KUL, SS17-SHO, SS20-BAR and SS21-BAR) revealed copper concentration in soil above than its average content in the sub-zone (Table 5.1.1).

The mean zinc content in soils of this sub-zone was found as 1.26 mg kg^{-1}. Five sample sites (SS12-ANG, SS14-KUL, SS16-SHO, SS19-BUD and SS20-BAR) record higher zinc content than its mean in the sub-zone. The concentration of zinc, pH and OM varied from 0.500-1.962 mg kg^{-1}, 5.88-7.44 and 3.02-5.24% respectively (Table 5.1.1).

The mean iodine content (3.7 µg L^{-1}) in drinking waters in the LFHs-2 was found more than the LFHs-1. The average pH of the drinking water was revealed as 7.64. The iodine content varied from 3.0-4.4 µg L^{-1} and pH from 7.34-7.87. The lower iodine content characterized TSm drinking water source at SS21-BAR and higher was found in TSm drinking water source at SS17-SHO (Table 5.1.2). In LFHs-2, out of 10 water sample sites, 4 sample sites (SS12-ANG, SS13-ANG, SS16-SHO and SS17-SHO) recorded higher iodine content than average iodine content (3.7 µg L^{-1}) in water (Table 5.1.2).

The behavior of copper in drinking waters in LFHs-2 was discovered unlike in LFHs-1. There was found slight accumulation of copper in waters than in the FHS-1. The mean copper content in drinking waters was found as 17.0 µg L^{-1} and mean pH of 7.64. The copper content at sample site level varied from 12.0-22.0 µg L^{-1}. The lower value was found in tap water fed by spring at SS13-ANG and SS18-BUD. While the higher value in tap water fed by spring was discovered at SS15-KUL. Six sample sites (SS14-KUL, SS15-KUL, SS16-SHO, SS17-SHO, SS20-BAR and SS21-BAR) out of 10 revealed higher copper content than its mean value in the sub-region (Table 5.1.2).

The LFHS-2 sub-zone recorded highest mean zinc content (118.7 µg L^{-1}) in the drinking waters than the LFHs-1. Five sample sites (SS13-ANG, SS15-KUL, SS16-SHO, SS18-SHO and SS21-BAR) revealed higher zinc content than the mean. The zinc concentration in the sub-region, varied from 19.0-217.0 µg L^{-1}. The lowest value was found in spring fed tap water at SS17-SHO with pH of 7.80 while highest amount of zinc was found in spring fed tap water at SS13-ANG with pH of 7.54. Both acidic and basic pH of water leads to lesser retention of metals in it (Table 5.1.2).

Summing up, the mean iodine content, pH and OM in soils of LFHs are 1.29 mg kg^{-1}, 6.76 and 3.56% respectively. The mean iodine content showed an increase with altitude from 1.26 mg kg^{-1} to 1.32 mg kg^{-1} with mean OM from 3.30% to 3.84% from LFHs-1 to LFHs-2. At sample site level, the total iodine concentration, pH and OM in soils varies from 0.95-1.65 mg kg^{-1}, 5.66-7.51 and 1.34-5.24% respectively. The SS4-KUL with soil type-81 which contains 0.95 mg kg^{-1} iodine has relatively acidic pH (6.70), low OM (1.34%) and non-calcareous character as compared to SS20-BAR with soil type-58 which contains 1.65 mg kg^{-1} iodine and has neutral pH (6.99), high OM (5.07%) and calcareous nature (Table 5.1.1).

The mean copper content, pH and OM in soils of LFHs were found as 2.34 mg kg^{-1}, 6.76 and 3.56% respectively. The average copper content increased with altitude from 2.11 mg kg^{-1} to 2.59 mg kg^{-1} from LFHs-1 to LFHs-2 with mean OM from 3.30% to 3.84%. The actual and total copper contents, pH and OM varied from 0.26-4.45 mg kg^{-1}, 5.66-7.51 and 1.34-5.24% respectively (Table 5.1.1). The lowest copper content was found in soil type-105 at SS8-BUD. This soil registers higher amount of OM in the foot hills though not highest copper content. The impact of OM was undermined by the other soil properties such as coarse texture, severe erosion and moderate stoniness. While as, the highest amount of copper was revealed in soil type-81 at SS17-SHO. The amount of copper in this soil at the particular site showed a mysterious relationship with pH and OM.

The mean zinc content in soils of LFHs was revealed as 1.190 mg kg^{-1}. The zinc concentration showed an association with pH and OM together. In LFHs, the mean zinc content increased with altitude from 1.13-1.26 from LFHs-1 to LFHs-2 with mean OM from 3.30-3.84% respectively. The zinc content, pH and OM varied from 0.500-1.962 mg kg^{-1}, 5.66-7.51 and 1.34-5.24% respectively (Table 5.1.1).

The mean iodine content and pH in the drinking waters in LFHs was found as 3.39 µg L^{-1} and 7.61. The iodine content varies from 2.2-4.4 µg L^{-1} and pH from 7.23-7.87 in the sample sites. The lower value of iodine was revealed in TSm drinking water source at SS8-BUD and higher value in TSg drinking water source at SS17-SHO (Table 5.1.2).

The mean copper content in drinking waters was found as 16.9 µg L^{-1} i.e., higher than the value in the whole study area. The copper content and pH varied from 5.0-26.0 µg L^{-1} and 7.23-7.87 respectively (Table 5.1.2).

So far average concentration of zinc in drinking water is concerned, it was found as 79.1 µg L^{-1} with mean pH of 7.61. The mean zinc content in drinking water showed a reasonable association the mean pH of the water. The mean zinc concentration increased from 43.1-118.7 µg L^{-1} with increase in mean pH from 7.59-7.64 from LFHs-1 to LFHs-2 respectively. The zinc content in drinking water varied from 16.0-217 µg L^{-1}. The lowest zinc content was found at SS1-ANG in spring fed tap water and highest at SS13-ANG in spring fed tap water (Table 5.1.2).

5.1.3. Concentration of Essential Trace Elements in Upper Foot Hill Settlements-(UFHs)

The average iodine content (1.24 mg kg^{-1}) in the soils of UFHs was found less than the LFHs. Generally, it should have been reverse. But, the increasing deforestation in the sparse forest covers and overgrazing of pastures decreases the organic content of the soils that leads to the pseudo or weak binding and hence retention of iodine in the soil. So, relatively low OM (3.40%) in the soils of UFHs lead to relatively low retention of iodine content in the soil. Furthermore, the iodine content, pH and OM in the soils of the region ranged from 0.90-1.55 mg kg^{-1}, 6.43-7.59 and 1.34-5.02% respectively (Table 5.1.1). Out of 10 soil sample sites, 6 soil sample sites (SS23-ANG, SS24-KUL, SS26-SHO, SS27-SHO, SS28-BUD and SS31-BAR) showed higher iodine concentration values than the average values (1.24 mg kg^{-1}) in the UFHs (Table 5.1.1).

The average copper concentration (1.90 mg kg^{-1}) in the UFHs is less than the mean values in LFHs. It could be due to the role of mean OM (3.40%) in the soil. In this zone, amount of copper, pH and OM ranged from 0.930-3.342 mg kg^{-1}, 6 .43-7.59 and 1.34-5.02%. The lowest amount of copper (0.930 mg kg^{-1}) was found in soil type-106 at SS23-ANG and highest value (3.342 mg kg^{-1}) in soil type-106 at SS31-BAR. Here, OM and pH play important role in the retention and distribution of copper in the soil. Out of 10 soil sample sites, 5 soil sample sites (SS24-KUL, SS26-SHO, SS27-SHO, SS29-BUD and SS31-BAR) recorded higher copper content than the mean value (1.90 mg kg^{-1}) in the zone (Table 5.1.1).

In the UFH sub-region, the mean zinc content in the soil was found as 1.157 mg kg^{-1}. The zinc content varied from 0.560-1.806 mg kg^{-1}. The lowest value was found in soil type-58 at SS30-BAR. Though the soil is calcareous in nature, it recorded lowest zinc content that may be ascribed to low OM (1.90%) and lowest pH (6.43) in it in the sub-zone. The highest zinc content was recorded by same soil type at SS26-SHO due to highest OM (5.02%) and relatively neutral pH (6.89) of it in the sub-zone. Five sample sites (SS22-ANG, SS24-KUL, SS25-KUL, SS26-SHO and SS29-BUD) revealed higher zinc content than its mean in the soils in the sub-zone (Table 5.1.1).

The iodine content in the drinking waters in UFHs was found as 2.8 µg L^{-1}. The iodine content varied from 2.2-3.5 µg L^{-1} (Table 5.1.2). This sub-region records the lower mean iodine content than LFHs, LFHs-1 and LFHs-2 because of high altitude. The high altitude limits the area of contribution wherefrom leached and dissolved iodides could reach the water sources. Moreover, atmospheric temperature that has a close connection with the soil atmosphere is comparatively low in high altitude areas, retards the processes of leaching and dissolution in soil environment. In UFHs, especially in deforested areas, loss of iodine in soil occurs during torrential and endured rainfalls. Also, iodine has high molecular weight due to which it tends to settle at lower altitudes if not interfered by an external force. Four sample sites showed less iodine content than mean value, two equal to mean value and others greater than it.

The UFH region revealed lowest mean copper content in drinking water than in LFHs. It was found as 16.2 µg L^{-1} with mean pH of 7.63. It varied from 12.0-22.0 µg L^{-1}. Six sample sites showed lower copper content than the mean value in this sub-region (Table 5.1.2).

The mean zinc content in drinking water was found as 41.7 µg L^{-1} with mean pH of 7.63. The zinc content in this sub-region ranged from 12.0-96.0 µg L^{-1}. Out of ten sample sites, seven recorded less zinc content than mean value (Table 5.1.2).

Therefore, the average iodine content in the soils of foot hill settlements becomes 1.27 mg kg^{-1} (Table 5.1.1). The average pH and OM values in the soils are 6.82 and 3.51% respectively (Table 5.1.1). At altitudinal level, the mean iodine content decreased from 1.29 mg kg^{-1} to 1.24 mg kg^{-1} from LFHs to UFHs with mean OM from 3.56% to 3.40% (Table 5.1.1). The total iodine content, pH and OM in the soil types varies from 0.90-1.65 mg kg^{-1}, 5.66-7.51 and 1.34-5.24% respectively (Table 5.1.1). The lowest value of 0.90 mg kg^{-1} is found in soil type-81 at SS25-KUL and highest value of 1.65 mg kg^{-1} in soil type-58 at SS20-BAR (Table 5.1.1). This is because of certain factors. At SS25-KUL, soil type-81 is characterized by low OM (2.91%) as compared to soil type-58 which contains high OM (5.07%) at SS20-BAR. Also, the soil type-58 is calcareous in nature. Figure 5.1.1 shows relationship of iodine concentration with organic matter in soil.

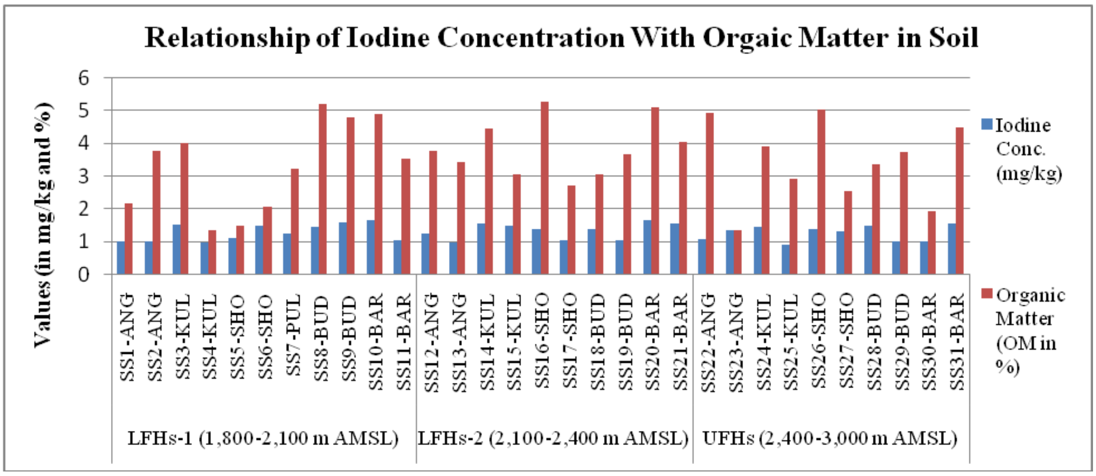


Fig. 5.1.1

The interpretation of Shapiro-Wilk's Normality test revealed that iodine concentration in soil samples was normally distributed for all the altitudinal zones (Table 5.1.3) and that there was non-homogeneity of variances as assessed by Levenes's test for Homogeneity of Variances (Table 5.1.4) in ANOVA. Therefore, Welch ANOVA and Games-Howell post-hoc tests were run on the data. There was a statistically significant difference in the mean iodine contents in the soils between and within the altitudinal zones as determined by one-way ANOVA ($F_{2,\ 12}$ =57.67, p=0.0001) and most appropriately by Welch ANOVA ($F_{2,\ 6.04}$ =63.032, p=0.0001) at significance level of 0.05 as shown in Table 5.1.5**.** A Games-Howell post-hoc multiple comparison test revealed highly significant variation between LFHs-1 and LFHs-2 (p=0.004), LFHs-1 and UFHs (p=0.002) and LFHs-2 and UFHs (p=0.001) (Table 5.1.5).

Table 5.1.3: Shapiro-Wilk's Normality Test in one-way ANOVA: Concentration of Essential Trace Elements in Soils and Drinking Waters

	Zones	Statistic	df	Sig. (p-value)
Iodine Content in Soil Samples	LFHs-1	0.821	5	0.119
	LFHs-2	0.894	5	0.377
	UFHs	0.978	5	0.921
Copper Content in Soil Samples	LFHs-1	0.987	5	0.967
	LFHs-2	0.881	5	0.314
	UFHs	0.771	5	0.046
Zinc Content in Soil Samples	LFHs-1	0.987	5	0.967
	LFHs-2	0.954	5	0.766
	UFHs	0.780	5	0.055
Iodine Content in Drinking Water Samples	LFHs-1	0.987	5	0.967
	LFHs-2	0.971	5	0.884
	UFHs	0.980	5	0.935
Copper Content in Drinking Water Samples	LFHs-1	0.989	5	0.975
	LFHs-2	0.987	5	0.967
	UFHs	0.987	5	0.967
Zinc Content in Drinking Water Samples	LFHs-1	0.987	5	0.967
	LFHs-2	0.989	5	0.975
	UFHs	0.987	5	0.967

Table 5.1.4: Levene's Test of Homogeneity of Variances in one-way ANOVA: Concentration of Essential Trace Elements in Soils and Drinking Waters

	Levene Statistic	df1	df2	Sig. (p-value)
Iodine Content in Soil Samples	6.355	2	12	0.013*
Copper Content in Soil Samples	5.713	2	12	0.018*
Zinc Content in Soil Samples	0.336	2	12	0.721
Iodine Content in Drinking Water Samples	0.109	2	12	0.898
Copper Content in Drinking Water Samples	0.003	2	12	0.997
Zinc Content in Drinking Water Samples	0.001	2	12	0.999

*Assumption of Homogeneity of Variances violated

Table 5.1.5: One-way ANOVA, Welch ANOVA and Games-Howell post-hoc Tests: Concentration of Essential Trace Elements in Soils

Iodine	**df**	**F**	**Sig. (p-value)**
Between altitudinal zones	2	57.67	0.0001
Within altitudinal zones	12		
Total	14		
Welch ANOVA	2, 6.04 (df1, df2)	63.032*	0.0001
LFHs-1 Vs LFHs-2	-	-	0.004
LFHs-1 Vs UFHs	-	-	0.002
LFHs-2 Vs UFHs	-	-	0.001
Copper			
Between altitudinal zones	2	5.68	0.0001
Within altitudinal zones	12		
Total	14		
Welch ANOVA	2, 5.39 (df1, df2)	1.515*	0.0001
LFHs-1 Vs LFHs-2	-	-	0.0001
LFHs-1 Vs UFHs	-	-	0.0001
LFHs-2 Vs UFHs	-	-	0.0001
Zinc (Tukey post hoc)			
Between altitudinal zones	2	1.25	0.0001
Within altitudinal zones	12		
Total	14		
LFHs-1 Vs LFHs-2	-	-	0.0001
LFHs-1 Vs UFHs	-	-	0.0001
LFHs-2 Vs UFHs	-	-	0.0001

The mean difference is significant at the 0.05 level.
*Asymptotically F distributed

The Shapiro-Wilk's Normality test revealed that iodine concentration in soil samples was normally distributed for both the altitudinal zones (Table 5.1.6) and that there was non-homogeneity of variances as assessed by Levenes's test for Equality of Variances (Table 5.1.7) in Independent Samples t-Test analysis. Therefore, Welch t-test was run on the data. A statistically significant difference was revealed in the mean iodine contents in the soils between the altitudinal zones (LFHs and UFHs) ($t_{4.539}$=9.129, p=0.0001) at the significance level of 0.05 as shown in Table 5.1.8.

Table 5.1.6: Shapiro-Wilk's Normality Test in Independent Samples t-Test: Concentration of Essential Trace Elements in Soils and Drinking Waters

	Zones	Statistic	df	Sig. (p-value)
Iodine Content in Soil Samples	LFHs	0.902	5	0.421
	UFHs	0.978	5	0.921
Copper Content in Soil Samples	LFHs	0.771	5	0.046*
	UFHs	0.872	5	0.057
Zinc Content in Soil Samples	LFHs	0.987	5	0.967
	UFHs	0.780	5	0.055
Iodine Content in Drinking Water Samples	LFHs	0.980	5	0.936
	UFHs	0.980	5	0.935
Copper Content in Drinking Water Samples	LFHs	0.988	5	0.972
	UFHs	0.987	5	0.967
Zinc Content in Drinking Water Samples	LFHs	0.988	5	0.971
	UFHs	0.987	5	0.967

*Though the assumption of Normality is a bit violated, the Independent t-Test can be safely used since it is robust to the violations of Normality

Table 5.1.7: Levene's Test for Equality of Variances in Independent Samples t-Test: Concentration of Essential Trace Elements in Soils and Drinking Waters

	F	Sig. (p-value)
Iodine Content in Soil Samples	8.184	0.021*
Copper Content in Soil Samples	3.571	0.095
Zinc Content in Soil Samples	0.539	0.484
Iodine Content in Drinking Water Samples	0.037	0.852
Copper Content in Drinking Water Samples	0.001	0.972
Zinc Content in Drinking Water Samples	0.000	0.983

*Assumption of Equality of Variances violated

Table 5.1.8: Independent Samples t-Test for Equality of Means: Concentration of Essential Trace Elements in Soils and Drinking Waters

	t	df	Sig. (2-tailed)
Iodine Content in Soil Samples			
Equal variances assumed	9.129	8	0.0001
Equal variances not assumed (Welch t-test)*	9.129	4.539	0.0001
Copper Content in Soil Samples			
Equal variances assumed	985.212	8	0.0001
Equal variances not assumed (Welch t-test)	985.212	5.882	0.0001
Zinc Content in Soil Samples			
Equal variances assumed	40.614	8	0.0001
Equal variances not assumed (Welch t-test)	40.614	7.391	0.0001
Iodine Content in Drinking Water Samples			
Equal variances assumed	1.942	8	0.089
Equal variances not assumed (Welch t-test)	1.942	7.892	0.089
Copper Content in Drinking Water Samples			
Equal variances assumed	0.307	8	0.767
Equal variances not assumed (Welch t-test)	0.307	7.998	0.767
Zinc Content in Drinking Water Samples			
Equal variances assumed	18.618	8	0.0001
Equal variances not assumed (Welch t-test)	18.618	7.999	0.0001

The mean difference is significant at the 0.05 level.

*Welch t-test figures are more appropriate since the assumption of Equality of variances was violated

Similarly, the average copper concentration in the soils of the study area was revealed as 2.20 mg kg^{-1} (Table 5.1.1). The mean pH and OM values were found as 6.82 and 3.51%. The mean copper concentration decreased with altitude from 2.34 mg kg^{-1} to 1.90 mg kg^{-1} from LFHs to UFHs with mean OM from 3.56% to 3.40%. The total copper concentration in soils at sample sites ranged from 0.26-4.45 mg kg^{-1}. Almost same results were found by Nazif, *et al*. (2006). They found that the AB-DTPA concentration of copper in the soils of Bhimber district of Azad Jammu and Kashmir varied from 0.59-4.38 mg kg^{-1}. The results are also in conformity with the results of Arokiyaraj, *et al*. (2011) and Wani, *et al*. (2013). Wani, *et al*. (2013) while analyzing the soils of Kupwara district found that the DTPA content of copper in soils varied from 0.26-3.90 mg kg^{-1} with mean value of 1.65 mg kg^{-1}. The pH and OM values varied from 5.66-7.51 and 1.34-5.24% respectively (Table 5.1.1). Though the soil type-105 at SS8-BUD experiences alkaline pH and high OM, it revealed lowest copper content of 0.26 mg kg^{-1}. It could be pinpointed that the soil type-105 is excessively drained, and coarse loamy in nature veneered on steep slopes. It is characterized by moderate stoniness and severe erosion. These characteristics might be responsible for undermining the impact of pH and OM in this case. Moreover, highest copper content was found at SS17-SHO in soil type-81 though pH and OM did not seem in conformation. Here again, the reason might be the fine loamy texture of the soil. These soils are also characterized by gentle slopes and so safe from enhanced erosion. So, it is clear that OM and clay content played important role in determining the concentration of copper in the soil. Same results were reported by Karim, *et al*. (1976), Katyal and Vlek (1985) and Wani, *et al*. (2013) in terms of relationship of copper with OM and clay fraction. Figure 5.1.2 shows relationship of copper concentration with organic matter in soil.

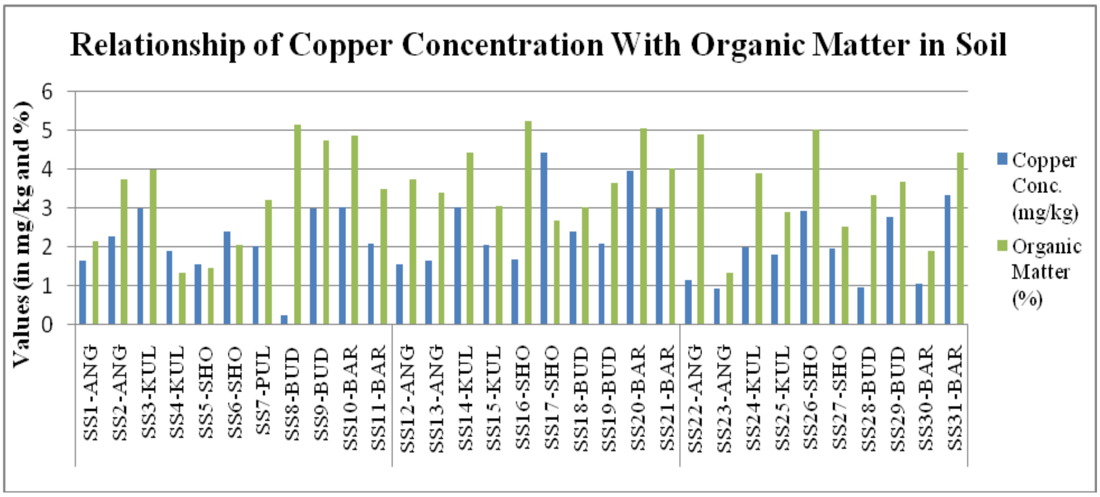


Fig. 5.1.2

The interpretation of Shapiro-Wilk's Normality test revealed that copper concentration in soil samples was normally distributed for all the altitudinal zones (Table 5.1.3) and that there was non-homogeneity of variances as assessed by Levenes's test for Homogeneity of Variances (Table 5.1.4) in ANOVA. Therefore, Welch ANOVA and Games-Howell post-hoc tests were run on the data. There was a statistically significant difference in the mean copper contents in the soils between and within the altitudinal zones as determined by one-way ANOVA ($F_{2,\ 12}$ =5.68, p=0.0001) and most appropriately by Welch ANOVA ($F_{2,\ 5.39}$ =1.515, p=0.0001) at significance level of 0.05 as shown in Table 5.1.5**.** A Games-Howell post-hoc multiple comparison test revealed highly significant variation between LFHs-1 and LFHs-2 (p=0.0001), LFHs-1 and UFHs (p=0.0001) and LFHs-2 and UFHs (p=0.0001) (Table 5.1.5).

The Shapiro-Wilk's Normality test revealed that copper concentration in soil samples was almost normally distributed for both the altitudinal zones (Table 5.1.6) and that there was homogeneity of variances as assessed by Levenes's test for Equality of Variances (Table 5.1.7) in Independent Samples t-Test analysis. Therefore, Independent Samples t-Test while assuming equal variances was run on the data. A statistically significant difference was revealed in the mean copper contents in the soils between the altitudinal zones (LFHs and UFHs) (t_8=985.212, p=0.0001) at the significance level of 0.05 as shown in Table 5.1.8.

The average zinc content in the soils of the study area was found as 1.179 mg kg^{-1} with average pH and OM of 6.82 and 3.51% respectively (Table 5.1.1). These are zinc deficient soils because the mean zinc concentration in the soils of the study area is very less than world average of zinc in soil (64 mg kg^{-1}). Clay and organic matter fix up zinc very efficiently at neutral and alkaline pH regimes in soil. Calcareous and organic soils record the highest background zinc contents in the area. The mean zinc concentration decreased with altitude from 1.190-1.157 mg kg^{-1} from LFHs to UFHs with mean OM from 3.56% to 3.40% respectively. The zinc content of different sample sites showed a variation from one another with respect to variation in pH, OM and other soil characters. The zinc content, pH and OM varied from 0.500-1.962 mg kg^{-1}, 5.66-7.51 and 1.34-5.24% respectively. The lowest zinc value of 0.500 mg kg^{-1} found at SS18-BUD in soil type-105 is due to relatively low pH (6.89) and low OM (3.02%) coupled with other soil characters such as severe erosion, moderate stoniness, coarse texture and excessively drained. The highest value of 1.962 mg kg^{-1} was found at SS14-KUL in soil type-58. It may be ascribed to alkaline pH (7.15) and relatively high OM (4.44%) together with calcareous, loamy and slight erosional character of the soil (Table 5.1.1). Almost same results were found by Nazif, *et al*. (2006). They found that the AB-DTPA concentration of zinc in the soils of Bhimber district of Azad Jammu and Kashmir varied from 0.74-2.08 mg kg^{-1}. The results were also in line those of the results of Talikdar, *et al*. (2009), Mahashabde and Patel (2012) and Wani, *et al*. (2013). Wani, *et al*. (2013) while analyzing the soils of the Kupwara district found that the DTPA-zinc content varied from 0.12-5.10 mg kg^{-1}. Same results were reported by Wani, *et al*. (2013) so far the relationship of zinc with OM, and pH is concerned. They reported that the concentration of zinc in soil increases with increase in OM and decrease in zinc availability (i.e., in soil solution) decreases with increase in pH (i.e., alkalinity). Figure 5.1.3 shows relationship of zinc concentration with organic matter in soil.

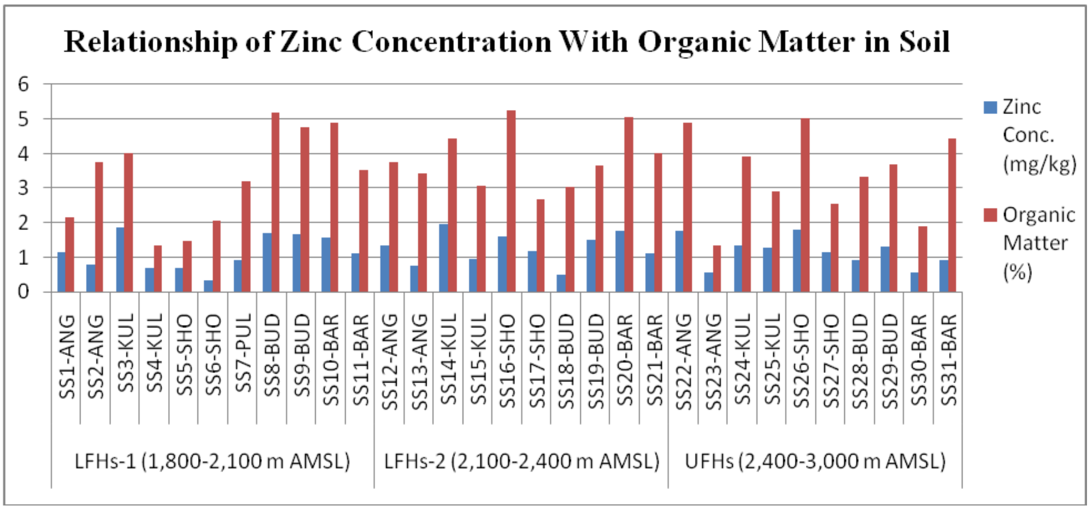


Fig. 5.1.3

The interpretation of Shapiro-Wilk's Normality test revealed that zinc concentration in soil samples was normally distributed for all the altitudinal zones (Table 5.1.3) and that Levenes's test for Homogeneity of Variances showed homogeneity of variances (Table 5.1.4) in ANOVA. Therefore, one-way ANOVA and Tukey post-hoc tests were run on the data. A statistically significant difference was observed in the mean zinc contents in the soils between and within the altitudinal zones as determined by one-way ANOVA ($F_{2,\ 12}$ =1.25; p=0.0001) at significance level of 0.05 as shown in Table 5.1.5**.** A Tukey post-hoc multiple comparison test revealed highly significant variation between LFHs-1 and LFHs-2 (p=0.0001), LFHs-1 and UFHs (p=0.0001) and LFHs-2 and UFHs (p=0.0001) (Table 5.1.5).

The study of Shapiro-Wilk's Normality test revealed that zinc concentration in soil samples was normally distributed for both the altitudinal zones (Table 5.1.6) and that there was homogeneity of variances as assessed by Levenes's test for Equality of Variances (Table 5.1.7) in Independent Samples t-Test analysis. Therefore, Independent Samples t-Test while assuming equal variances was run on the data. A statistically significant difference was revealed in the mean zinc contents in the soils between the altitudinal zones (LFHs and UFHs) (t_8=40.614, p=0.0001) at the significance level of 0.05 as shown in Table 5.1.8.

The iodine in the form of iodides in drinking water sources of the study area is derived from leaching of iodine from surrounding soils in surface waters and dissolution of iodine from geological and lithological setting in ground waters. In India, it has been found that the iodine content of drinking water in goitrous areas ranges from 3-16 µg L^{-1} and 5-64 µg L^{-1} in non-goitrous areas (Srilakshmi, 2012). As per the above standard, the whole foot hill region falls under goitrous areas. The average iodine content in drinking waters was found as 3.2 µg L^{-1} (Table 5.1.2). Again, it is less than the world average of iodine in fresh waters (8.7 µg L^{-1}). The iodine content varies from 2.2-4.4 µg L^{-1} (Table 5.1.2). The lowest value was found in TSm water source with alkaline pH of 7.73 at SS8-BUD and Sg with pH of 7.82 at SS27-BUD and highest in TSm water source with too alkaline pH of 7.80 at SS17-SHO. All the drinking water sources were found alkaline in nature.

The analysis of Shapiro-Wilk's Normality test revealed that iodine concentration in water samples was normally distributed for all the altitudinal zones (Table 5.1.3) and that there was homogeneity of variances as assessed by Levenes's test for Homogeneity of Variances (Table 5.1.4) in ANOVA. Therefore, one-way ANOVA and Tukey post-hoc tests were run on the data. There was a statistically significant difference in the mean iodine contents in the drinking water samples between and within the altitudinal zones as determined by one-way ANOVA ($F_{2, 12}$ =7.34, p=0.008) at significance level of 0.05 as shown in Table 5.1.9**.** A Tukey post-hoc multiple comparison test revealed significant variation between LFHs-1 and LFHs-2 (p=0.027), and LFHs-2 and UFHs (p=0.01) except LFHs-1 and UFHs (p=0.856) (Table 5.1.9).

Table 5.1.9: One-way ANOVA and Tukey post-hoc Tests: Concentration of Essential Trace Elements in Drinking Waters

Iodine	**df**	**F**	**Sig. (p-value)**
Between altitudinal zones	2	7.34	0.008
Within altitudinal zones	12		
Total	14		
LFHs-1 Vs LFHs-2	-	-	0.027
LFHs-1 Vs UFHs	-	-	0.856
LFHs-2 Vs UFHs	-	-	0.01
Copper			
Between altitudinal zones	2	0.082	0.922
Within altitudinal zones	12		
Total	14		
LFHs-1 Vs LFHs-2	-	-	0.982
LFHs-1 Vs UFHs	-	-	0.974
LFHs-2 Vs UFHs	-	-	0.915
Zinc			
Between altitudinal zones	2	958.6	0.0001
Within altitudinal zones	12		
Total	14		
LFHs-1 Vs LFHs-2	-	-	0.0001
LFHs-1 Vs UFHs	-	-	0.773
LFHs-2 Vs UFHs	-	-	0.0001

The mean difference is significant at the 0.05 level.

The Shapiro-Wilk's Normality test revealed that iodine concentration in water samples was normally distributed for both the altitudinal zones (Table 5.1.6) and that there was homogeneity of variances as assessed by Levenes's test for Equality of Variances (Table 5.1.7) in Independent Samples t-Test analysis. Therefore, Independent Samples t-Test while assuming equal variances was run on the data. A statistically insignificant difference was revealed in the mean iodine contents in the drinking water samples between the altitudinal zones (LFHs and UFHs) (t_8=1.942, p=0.089) at the significance level of 0.05 as shown in Table 5.1.8. It becomes clear here that besides altitude certain other factors determine the concentration of iodine in the drinking waters. pH (and certain other factors) plays an important role.

In water, copper is highly mobile. Its concentrations in drinking water sources vary as a result of variations in water characteristics, such as pH, hardness and copper availability in the distribution system. The slightly acidic or very soft nature of water causes leaching of copper from distribution systems or even the soils. The average concentration of copper and pH in the drinking waters of the study area were found as 16.6 µg L^{-1} and 7.62 respectively. This value of 16.6 µg L^{-1} is more than world mean copper content found in fresh waters (1.48 µg L^{-1}). But, it does not mean that the copper content in drinking waters in the foot hills is sufficient for the healthy well being of the people. It is very below the requirement. For instance, if a person drinks three liters of non-boiled water, he swallows only about 50 µgs of copper. Then, once the copper in water goes into the digestive system, its assimilation is determined by a couple of factors. So, there is chance of reduction in its assimilation in the body. The total human requirement of copper is 2 mg d^{-1} normal $person^{-1}$. According to Bureau of Indian Standards (2009), the acceptable limit or required amount of copper in drinking water should be 50 µg L^{-1}. The copper content in drinking waters in the foot hills ranged from 5.0-26.0 µg L^{-1}. The results are almost same as reported by Jeelani (2010). He while analyzing spring waters of Anantnag district found that the copper content varied from 10-100 µg L^{-1}. The lower value of it was revealed in tap water fed by a spring source at SS5-SHO. The higher value was found in tap water fed by a spring at SS10-BAR. The drinking waters at the sample sites recorded alkaline pH ranging from 7.23-7.87 (Table 5.1.2).

The analysis of Shapiro-Wilk's Normality test revealed that copper concentration in water samples was normally distributed for all the altitudinal zones (Table 5.1.3) and that there was homogeneity of variances as assessed by Levenes's test for Homogeneity of Variances (Table 5.1.4) in ANOVA. Therefore, one-way ANOVA and Tukey post-hoc tests were run on the data. There was a statistically insignificant difference in the mean copper contents in the drinking water samples between and within the altitudinal zones as determined by one-way ANOVA ($F_{2,\ 12}$ =0.082, p=0.922) at significance level of 0.05 as shown in Table 5.1.9. A Tukey post-hoc multiple comparison test also revealed insignificant variation between LFHs-1 and LFHs-2 (p=0.982), and LFHs-2 and UFHs (p=0.915) and LFHs-1 and UFHs (p=0.974) (Table 5.1.9).

The Shapiro-Wilk's Normality test revealed that copper concentration in water samples was normally distributed for both the altitudinal zones (Table 5.1.6) and that there was homogeneity of variances as assessed by Levenes's test for Equality of Variances (Table 5.1.7) in Independent Samples t-Test analysis. Therefore, Independent Samples t-Test while assuming equal variances was run on the data. A statistically insignificant difference was revealed in the mean copper contents in the drinking water samples between the altitudinal zones (LFHs and UFHs) (t_8=0.307, p=0.767) at the significance level of 0.05 as shown in Table 5.1.8. It becomes clear here that besides altitude certain other factors determine the concentration of iodine in the drinking waters. pH (and certain other factors) plays an important role.

The main source of zinc in water is the soil particles containing zinc eroded from surrounding soils. The average zinc content in the drinking waters of the study area was found as 67.0 µg L^{-1} with mean pH of 7.62. It means that zinc content in waters of foot hills is very high than world average for river water (0.6 µg L^{-1}). But, it does not mean that it is sufficient for human health. The total human requirement of zinc varies from 10-15 mg $person^{-1}day^{-1}$. According to BIS (2009), the acceptable or required quantity of zinc in drinking water should be 5000 µg L^{-1}. The mean zinc content showed decrease from 79.1-41.7 µg L^{-1} from LFHs to UFHs. The results are almost same as reported by Jeelani (2010). He while analyzing spring waters of Anantnag district found that the zinc content varied from 100-2500 µg L^{-1}.The relatively higher zinc content in LFHs may be due to leaching of zinc from agricultural and horticultural soils. The zinc content in drinking water varied from 12.0-217 µg L^{-1}. The lowest zinc content was found at SS31-BAR in spring water and highest at SS13-ANG in spring fed tap water (Table 5.1.2).

The study of Shapiro-Wilk's Normality test revealed that zinc concentration in water samples was normally distributed for all the altitudinal zones (Table 5.1.3) and that there was homogeneity of variances as assessed by Levenes's test for Homogeneity of Variances (Table 5.1.4) in ANOVA. Therefore, one-way ANOVA and Tukey post-hoc tests were run on the data. There was a statistically significant difference in the mean zinc contents in the drinking water samples between and within the altitudinal zones as determined by one-way ANOVA ($F_{2,\ 12}$ =958.6, p=0.0001) at significance level of 0.05 as shown in Table 5.1.9. A Tukey post-hoc multiple comparison test also revealed significant variation between LFHs-1 and LFHs-2 (p=0.0001), and LFHs-2 and UFHs (p=0.0001) except LFHs-1 and UFHs (p=0.773) (Table 5.1.9).

The Shapiro-Wilk's Normality test revealed that the data zinc concentration in water samples was normally distributed for both the altitudinal zones (Table 5.1.6) and that there was homogeneity of variances as assessed by Levenes's test for Equality of Variances (Table 5.1.7) in Independent Samples t-Test analysis. Therefore, Independent Samples t-Test while assuming equal variances was run on the data. A statistically significant difference was revealed in the mean zinc contents in the drinking water samples between the altitudinal zones (LFHs and UFHs) (t_8=18.618, p=0.0001) at the significance level of 0.05 as is evident from Table 5.1.8.

5.2. SOCIO-ECONOMIC DETERMINANTS OF HUMAN HEALTH

The essential trace elements are very important for the human health. Since, they primarily occur in rocks and are transferred to the soil and water systems through a complex web of processes wherefrom their exposure for humans is increased. It is from here that these elements enter into the food chain and reach the human body leading to their imprints in terms of different states of health. The amount of a particular element that reaches a human body from the food chain depends upon a series of intervening human activities or factors such as dependence on local/non-local foods, amount of food taken, type of food taken, use of boiled or non-boiled water, methods of cooking, type of salt used, income level of the people and the like. These socio-economic factors limit the quantity of trace elements in the food intake. These factors act as links between the human body and the food chains and determine the deficiency or toxicity of a particular element in the human body.

For the achievement of the present work, the factors such as dependence of people on local and non-local foods, use of iodized salt, use of boiled or non-boiled water, income level of the people, type of food taken (composition of food: vegetarian or non-vegetarian), methods of cooking used by the people were taken into consideration.

5.2.1. Dependence of People on Local Foods

Food is the basic unavoidable necessity of human beings. The human body requires dozens of minerals such as calcium, magnesium, potassium, copper, zinc, iron, selenium, and many more for its healthy survival and maintenance. The trace elements are neither manufactured nor stored inside the human body. Therefore, it is clear that food as diet is the main source of minerals including trace ones for human body.

The composition of food in terms of different nutrients reflects the composition of the soil and to certain extent water (used for irrigation). If the soil is deficient in certain nutrients, it is certain that the plants and the food products would be deficient in those nutrients. Secondly, the nutrient status and health of humans expresses the nutrient status in their diet, dependence on local or market foods, vegetarian or non-vegetarian diet and the like. If the soil and water especially drinking water are deficient in certain nutrients and the people have greater dependence on local foods and untreated (meaning there is no addition of nutrients through human intervention) water, there would be significant prevalence and incidence of health disorders related to the particular nutrients.

The locally cultivated foods which are plant-based diets are often associated with deficits in nutrients like calcium, iron, zinc and some vitamins (Gibson, *et al*., 2006). An important factor contributing to these deficiencies is that the bioavailability, the proportion of an ingested trace element in food that is absorbed and utilized for normal metabolic and physiological functions or storage (Jackson, 1997), of these foods is poor. Bioavailability is determined by both dietary and host related factors (Fairweather-Tait and Hurrell, 1996). It has also been found that fruits and green leafy vegetables contain only modest amounts of trace elements because of their high water content (Sorenson, *et al*., 1987). Fruits and vegetables are found to be poor sources of iodine. In general, vegetarian diets have lesser bioavailability of micronutrients than the non-vegetarian foods. Traditionally, it was believed that humans derive iodine from consumption of crops and vegetables, etc. But, this may be true only in coastal areas. In inland areas especially mountainous ones, the plant based diet will provide only a small fraction of iodine. In this context, it has been demonstrated that vegetarian diets result in low iodine, which could lead to iodine deficiency (Davidsson, 1990). Humans also derive iodine from water and possibly air. It has been found that iodine derived from drinking water seldom contributes more than 10% of the daily iodine requirement (Fuge, 2005). The inhalation of some iodine from atmosphere is indeed significant in near-coastal environments. It might be inhaled in areas remote from the sea but that amount cannot be more than 0.5 µg d^{-1} (Nordic Project Group, 1995).

In the area under study, the people depend mostly on locally cultivated food items. On the whole, it is clear from the table 5.2.1 that the households/people in the sample villages have two-third percent (63.89%) dependence on locally cultivated essential trace element deficient vegetable foods and only about 36.11% food including both vegetarian and non-vegetarian is bought from the market. The dependence of people on local vegetarian food items increases from LFHs to UFHs from 56.54% to 71.25% respectively and dependence on market foods decreases from 43.46% to 28.75% from LFHs to UFHs respectively. Within the LFHs, there is a slight variation in the dependence of people on local food stuffs. It decreases from 57.25% to 55.83% from LFHs-1 to LFHs-2 respectively. At the sample village level, the highest dependence of people on local foods of 75.0% was found in SS30-BAR (in UFHs) and lowest dependence of 47.30% was found in SS10-BAR (LFHS-1) respectively.

The study of Shapiro-Wilk's Normality test revealed that data pertaining to dependence of people on locally cultivated food items was normally distributed for all the altitudinal zones (Table 5.2.2) and that there was homogeneity of variances as assessed by Levenes's test for Homogeneity of Variances (Table 5.2.3). Therefore, one-way ANOVA and Tukey post-hoc tests were run on the data. There was a statistically significant difference in the mean dependence of people on locally cultivated food items between and within the altitudinal zones as determined by one-way ANOVA ($F_{2,\ 6}$ =185.564, p=0.0001) at significance level of 0.05 as shown in Table 5.2.4**.** A Tukey post-hoc multiple comparison test also revealed significant variation between LFHs-1 and UFHs (p=0.0001), and LFHs-2 and UFHs (p=0.0001) except LFHs-1 and LFHs-2 (p=0.151) (Table 5.2.4). Therefore, it becomes clear that altitude is not the only factor to determine the dependence of people on local foods.

The Shapiro-Wilk's Normality test revealed that the data pertaining to dependence of people on locally cultivated food items was normally distributed for both the altitudinal zones (Table 5.2.5) and that there was homogeneity of variances as assessed by Levenes's test for Equality of Variances (Table 5.2.6). Therefore, Independent Samples t-Test while assuming equal variances was run on the data. A statistically significant difference was revealed in the mean dependence of people on locally cultivated food items between the altitudinal zones (LFHs and UFHs) (t_4=-17.116, p=0.0001) at the significance level of 0.05 as shown in Table 5.2.7.

Table 5.2.1: Dependence of People on Locally Cultivated Food Items

Macro Region	Micro Region	Sample Villages	Number of Households Surveyed	Food Purchased from Market (%)	Dependence on Local Foods (%)
LFHs	LFHs-1	SS1-ANG	08	37.80	62.20
		SS2-ANG	52	43.50	56.50
		SS3-KUL	14	38.00	62.00
		SS4-KUL	09	45.20	54.80
		SS5-SHO	05	44.00	56.00
		SS6-SHO	22	39.20	60.80
		SS7-PUL	14	38.90	61.10
		SS8-BUD	33	47.00	57.00
		SS9-BUD	09	42.90	57.10
		SS10-BAR	04	52.70	47.30
		SS11-BAR	08	41.00	59.00
	Total		**178**	**42.75**	**57.25**
	LFHs-2	SS12-ANG	29	30.17	69.83
		SS13-ANG	25	43.00	57.00
		SS14-KUL	08	42.60	57.40
		SS15-KUL	27	44.20	55.80
		SS16-SHO	61	49.90	50.10
		SS17-SHO	30	44.50	55.50
		SS18-BUD	52	45.00	55.00
		SS19-BUD	06	47.30	52.70
		SS20-BAR	31	51.00	49.00
		SS21-BAR	05	44.00	56.00
	Total		**274**	**44.17**	**55.83**
Total			**452**	**43.46**	**56.54**
UFHs	UFHs	SS22-ANG	14	32.5	67.50
		SS30-BAR	05	25.00	75.00
	Total		**19**	**28.75**	**71.25**
Grand Total			**471**	**36.11**	**63.89**

Source: Sample Survey, 2013

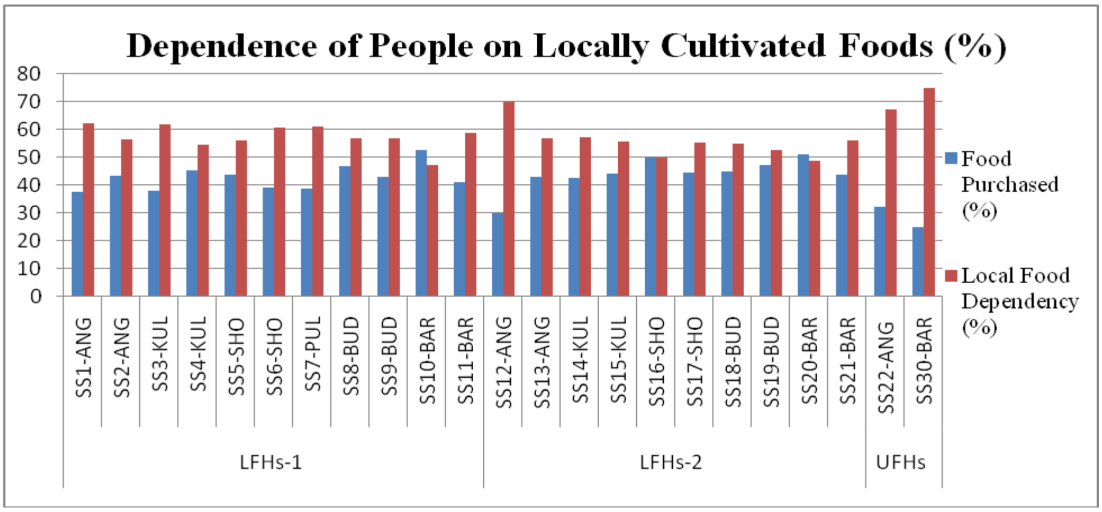


Fig. 5.2.1

Table 5.2.2: Shapiro-Wilk's Normality Test in one-way ANOVA: Dependence of People on Locally Cultivated Food Items (%) and Inappropriate Methods of Cooking Food (%)

	Zones	Statistic	df	Sig. (p-value)
Dependence of People on Locally Cultivated Food Items (%)	LFHs-1	0.998	3	0.910
	LFHs-2	1.000	3	0.972
	UFHs	0.999	3	0.956
Methods of Cooking Food (%)	LFHs-1	0.999	3	0.956
	LFHs-2	1.000	3	1.000
	UFHs	1.000	3	1.000

Table 5.2.3: Levene's Test of Homogeneity of Variances in one-way ANOVA: Dependence of People on Locally Cultivated Food Items (%) and Inappropriate Methods of Cooking Food (%)

	Levene Statistic	df1	df2	Sig. (p-value)
Dependence of People on Locally Cultivated Food Items (%)	0.038	2	6	0.963
Methods of Cooking Food (%)	0.005	2	6	0.995

Table 5.2.4: One-way ANOVA and Tukey post-hoc Tests: Dependence of People on Locally Cultivated Food Items (%) and Inappropriate Methods of Cooking Food (%)

		df	F	Sig. (p-value)
Dependence of People on Locally Cultivated Food Items (%)	Between altitudinal zones	2	185.564	0.0001
	Within altitudinal zones	6		
	Total	8		
	LFHs-1 Vs LFHs-2	-	-	0.151
	LFHs-1 Vs UFHs	-	-	0.0001
	LFHs-2 Vs UFHs	-	-	0.0001
Methods of Cooking Food (%)	Between altitudinal zones	2	326.716	0.0001
	Within altitudinal zones	6		
	Total	8		
	LFHs-1 Vs LFHs-2	-	-	0.014
	LFHs-1 Vs UFHs	-	-	0.0001
	LFHs-2 Vs UFHs	-	-	0.0001

The mean difference is significant at the 0.05 level.

Table 5.2.5: Shapiro-Wilk's Normality Test in Independent Samples t-Test: Dependence of People on Locally Cultivated Food Items (%) and Inappropriate Methods of Cooking Food (%)

	Zones	Statistic	df	Sig. (p-value)
Dependence of People on Locally Cultivated Food Items (%)	LFHs	1.000	3	0.975
	UFHs	0.999	3	0.956
Methods of Cooking Food (%)	LFHs	1.000	3	1.000
	UFHs	1.000	3	1.000

Table 5.2.6: Levene's Test for Equality of Variances in Independent Samples t-Test: Dependence of People on Locally Cultivated Food Items (%) and Inappropriate Methods of Cooking Food (%)

	F	Sig. (p-value)
Dependence of People on Locally Cultivated Food Items (%)	0.012	0.917
Methods of Cooking Food (%)	0.0001	1.000

Table 5.2.7: Independent Samples t-Test for Equality of Means: Dependence of People on Locally Cultivated Food Items (%) and Inappropriate Methods of Cooking Food (%)

	t	df	Sig. (2-tailed)
Dependence of People on Locally Cultivated Food Items (%)			
Equal variances assumed	-17.116	4	0.0001
Equal variances not assumed (Welch t-test)	-17.116	3.974	0.0001
Methods of Cooking Food (%)			
Equal variances assumed	22.191	4	0.0001
Equal variances not assumed (Welch t-test)	22.191	4.000	0.0001

The mean difference is significant at the 0.05 level.

5.2.2. Cooking Methods

Some foods are taken in raw form while most of them require some processing to bring desired changes in them before eating. Simply, cooking is a process of subjecting food to the action of heat under dry or wet/moist conditions. Generally, foods are cooked to sterilize and soften them, increase taste and variety and improve digestibility and nutrient availability. Cooking occurs by moist and dry heat. The moist heat involves water and steam and the dry heat refers to air or fat. Cooking methods have a tremendous role in changing the bioavailability of nutrients in the food and causing the loss or gain of nutrients in the food.

From the Table 5.2.8, it becomes obvious that about 69.64% of the households employed inappropriate methods of cooking foods or appropriate ones in an inappropriate way. They resort to deep and long period braising, blanching, frying and boiling methods of cooking that cause nutrient loss or make them non-bioavailable. There is a little variation in the percentage of households employing these cooking methods from LFHs to UFHs. It varies from 69.69% to 68.42% from LFHs to UFHs respectively. These cooking methods were mostly employed in LFHs-1 than other zones and sub-zones of foot hill settlements. In LFHs-1, about 75.84% households employed these methods. When long period and deep cooking is involved in these methods of cooking, high temperatures are employed that lead to denaturation of proteins and minerals. Also, use of water and its discarding after boiling involved in cooking adds to the problem of loss of nutrients. Deep fat frying impairs digestion making nutrients non-bioavailable.

The study of Shapiro-Wilk's Normality test revealed that data pertaining to use of inappropriate methods of cooking food was normally distributed for all the altitudinal zones (Table 5.2.2) and that there was homogeneity of variances as assessed by Levenes's test for Homogeneity of Variances (Table 5.2.3). Therefore, one-way ANOVA and Tukey post-hoc tests were run on the data. There was a statistically significant difference in the mean use of inappropriate methods of cooking food between and within the altitudinal zones as determined by one-way ANOVA ($F_{2,\ 6}$ =326.716, p=0.0001) at significance level of 0.05 as shown in Table 5.2.4**.** A Tukey post-hoc multiple comparison test also revealed significant variation between LFHs-1 and UFHs (p=0.0001), LFHs-2 and UFHs (p=0.0001) and LFHs-1 and LFHs-2 (p=0.014) (Table 5.2.4).

The Shapiro-Wilk's Normality test revealed that the data pertaining to use of inappropriate methods of cooking food was normally distributed for both the altitudinal zones (Table 5.2.5) and that there was homogeneity of variances as assessed by Levenes's test for Equality of Variances (Table 5.2.6). Therefore, Independent Samples t-Test while assuming equal variances was run on the data. A statistically significant difference was revealed in the mean use of inappropriate methods of cooking food between the altitudinal zones (LFHs and UFHs) (t_4=22.191, p=0.0001) at the significance level of 0.05 as shown in Table 5.2.7.

Table 5.2.8: Methods of Cooking Food

Macro Region	Micro Region	Sample Villages	Households Surveyed (100%)	Households using different Methods of Cooking (%)	
				Deep[1]	Light[2]
LFHs	LFHs-1	SS1-ANG	08	8 (100)	0 (0.0)
		SS2-ANG	52	43 (82.7)	9 (17.3)
		SS3-KUL	14	12 (85.7)	2 (14.3)
		SS4-KUL	09	7 (77.8)	2 (22.2)
		SS5-SHO	05	3 (60.0)	2 (40.0)
		SS6-SHO	22	18 (81.8)	4 (18.2)
		SS7-PUL	14	11 (78.6)	3 (21.4)
		SS8-BUD	33	19 (57.6)	14 (42.4)
		SS9-BUD	09	7 (77.8)	2 (22.2)
		SS10-BAR	04	1 (25.0)	3 (75.0)
		SS11-BAR	08	6 (75.0)	2 (25.0)
	Total		**178**	**135 (75.84)**	**43 (24.16)**
	LFHs-2	SS12-ANG	29	25(86.2)	4(13.8)
		SS13-ANG	25	20(80.0)	5(20.0)
		SS14-KUL	08	6 (75.0)	2 (25.0)
		SS15-KUL	27	19 (70.4)	8 (29.6)
		SS16-SHO	61	30 (49.2)	31 (50.8)
		SS17-SHO	30	22 (73.4)	8 (26.6)
		SS18-BUD	52	37 (71.1)	15 (28.9)
		SS19-BUD	06	4 (66.7)	2 (33.3)
		SS20-BAR	31	13 (41.9)	18 (48.1)
		SS21-BAR	05	4 (80.0)	1 (20.0)
	Total		**274**	**180 (65.69)**	**94 (34.31)**
Total			**452**	**315 (69.69)**	**137 (30.31)**
UFHs	UFHs	SS22-ANG	14	12(85.7)	2(14.3)
		SS30-BAR	05	1 (20.0)	4 (80.0)
	Total		**19**	**13 (68.42)**	**6 (31.58)**
Grand Total			**471**	**328 (69.64)**	**143 (30.36)**

Source: Sample Survey, 2013

Note: Deep[1]=Long period Braising/Blanching/Frying, Light[2]=Short period Braising/Blanching/Frying

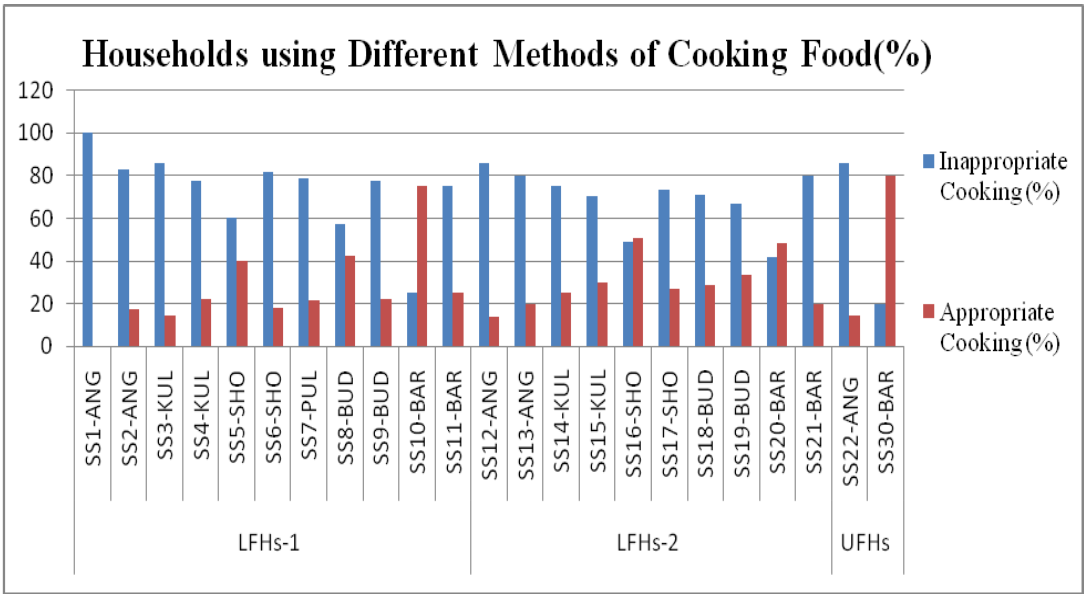


Fig. 5.2.2

5.2.3. Use of Iodized Salt

Since, iodine is the important trace element that is required by human body for better health and survival. It is well established fact that the natural soils and waters except the coastal soils and sea waters are deficient in iodine. The use of iodine fortified salt or iodized salt is necessary to combat the iodine deficiency disorders.

From the Table 5.2.9, it is clear that about 77.92% of the households use iodized salt and 22.08% households rely on rock salt in the study area. The use of iodized salt decreases with altitude from LFHs to UFHs from 80.08% to 26.32% respectively. But, in the LFHs, it slightly increases from LFHs-1 to LFHs-2 from 79.2% to 80.65% respectively. Here, again the factors of low economical base and lesser know how lead to lesser use of iodized salt with altitude.

The analysis of Shapiro-Wilk's Normality test revealed that data pertaining to households using iodized salt was normally distributed for all the altitudinal zones (Table 5.2.10) and that there was homogeneity of variances as assessed by Levenes's test for Homogeneity of Variances (Table 5.2.11). Therefore, one-way ANOVA and Tukey post-hoc tests were run on the data. There was a statistically significant difference in the average of households using iodized salt between and within the altitudinal zones as determined by one-way ANOVA ($F_{2,6}$ =1.761, p=0.0001) at significance level of 0.05 as shown in Table 5.2.12**.** A Tukey post-hoc multiple comparison test also revealed significant variation between LFHs-1 and UFHs (p=0.0001), and LFHs-2 and UFHs (p=0.0001) except LFHs-1 and LFHs-2 (p=0.068) (Table 5.2.12). Therefore, it becomes clear that altitude is not the only factor to determine the use of iodized salt by the people.

The Shapiro-Wilk's Normality test revealed that the data pertaining to use of iodized salt by the people was normally distributed for both the altitudinal zones (Table 5.2.13) and that there was homogeneity of variances as assessed by Levenes's test for Equality of Variances (Table 5.2.14). Therefore, Independent Samples t-Test while assuming equal variances was run on the data. A statistically significant difference was revealed in the mean use of iodized salt by the people between the altitudinal zones (LFHs and UFHs) (t_4=51.403, p=0.0001) at the significance level of 0.05 as shown in Table 5.2.15.

5.2.4. Use of Boiled Drinking Water

Drinking water serves as one of the important sources of trace elements where it is rich in them and if taken without boiling. If it is deficient in trace minerals, it contributes very less to the human health. Due to the threat of presence of coliforms, people generally drink boiled water. But, the boiling of water couples the loss of nutrients from it. Since, iodine is a volatile element; it is easily lost from water during boiling. So, drinking of boiled water acts synergistically to lead to different trace element related deficiency diseases in the human body.

About half of the population drinks boiled water in the foot hills. From the Table 5.2.9, it is clear that about 42.46% of the households use boiled water for drinking. The use of boiled drinking water decreases dramatically with altitude from LFHs to UFHs from 44.25% to 0.0% respectively. But, within the LFHs, the trend is opposite wherein the use of boiled drinking water increases from LFHs-1 to LFHs-2 from 55.06% to 60.87% respectively.

The analysis of Shapiro-Wilk's Normality test revealed that data pertaining to households drinking boiled water was normally distributed for LFHs-1 and LFHs-2 and constant for UFHs (since there was no household drinking boiled water in the UFHs) (Table 5.2.10) and that there was homogeneity of variances as assessed by Levenes's test for Homogeneity of Variances (Table 5.2.11). Therefore, one-way ANOVA and Tukey post-hoc tests were used to analyze the data. There was a statistically significant difference in the average of households drinking boiled water between and within the altitudinal zones as determined by one-way ANOVA ($F_{2, 6}$ =2.929, p=0.0001) at significance level of 0.05 as shown in Table 5.2.12**.** A Tukey post-hoc multiple comparison test also revealed significant variation between LFHs-1 and UFHs (p=0.0001), LFHs-2 and UFHs (p=0.0001) and LFHs-1 and LFHs-2 (p=0.0001) (Table 5.2.12).

The Shapiro-Wilk's Normality test revealed that the data pertaining to households drinking boiled water was normally distributed for LFHs and constant for UFHs (since there was no household drinking boiled water in the UFHs) (Table 5.2.13) and that there was homogeneity of variances as assessed by Levenes's test for Equality of Variances (Table 5.2.14). Therefore, Independent Samples t-Test while assuming equal variances was run on the data. A statistically significant difference was revealed in the mean of households drinking boiled water between the altitudinal zones (LFHs and UFHs) (t_4=78.920, p=0.0001) at the significance level of 0.05 as shown in Table 5.2.15.

Table 5.2.9: Households using Iodized Salt and Drinking Boiled Water

Macro Region	Micro Region	Sample Villages	Number of Households Surveyed (100%)	Households Using Iodized Salt (%)	Households Drinking Boiled Water (%)
LFHs	LFHs-1	SS1-ANG	08	6(75.0)	6(75)
		SS2-ANG	52	40(76.9)	35(67.3)
		SS3-KUL	14	11(78.6)	9(64.3)
		SS4-KUL	09	7(77.8)	5(55.6)
		SS5-SHO	05	4(80.0)	3(60.0)
		SS6-SHO	22	18(81.8)	10(45.5)
		SS7-PUL	14	10(71.4)	8(57.2)
		SS8-BUD	33	27(81.8)	14(42.4)
		SS9-BUD	09	8(88.9)	4(44.4)
		SS10-BAR	04	4(100.0)	1(25.0)
		SS11-BAR	08	6(75.0)	3(37.5)
	Total		**178**	**141(79.2)**	**98(55.06)**
	LFHs-2	SS12-ANG	29	22(75.8)	14(48.3)
		SS13-ANG	25	19(76.0)	10(40)
		SS14-KUL	08	6(75.0)	4(50.0)
		SS15-KUL	27	22(81.5)	12(44.5)
		SS16-SHO	61	51(83.6)	21(34.4)
		SS17-SHO	30	25(83.4)	12(40.0)
		SS18-BUD	52	42(80.7)	23(44.2)
		SS19-BUD	06	5(83.4)	2(33.4)
		SS20-BAR	31	26(83.8)	12(38.7)
		SS21-BAR	05	3(60.0)	2(40.0)
	Total		**274**	**221(80.65)**	**112(60.87)**
Total			**452**	**362(80.08)**	**200(44.25)**
UFHs	UFHs	SS22-ANG	14	2(14.3)	0(00)
		SS30-BAR	05	3(60.0)	0(00)
	Total		**19**	**5(26.32)**	**0(00)**
Grand Total			**471**	**367(77.92)**	**200(42.46)**

Source: Sample Survey, 2013

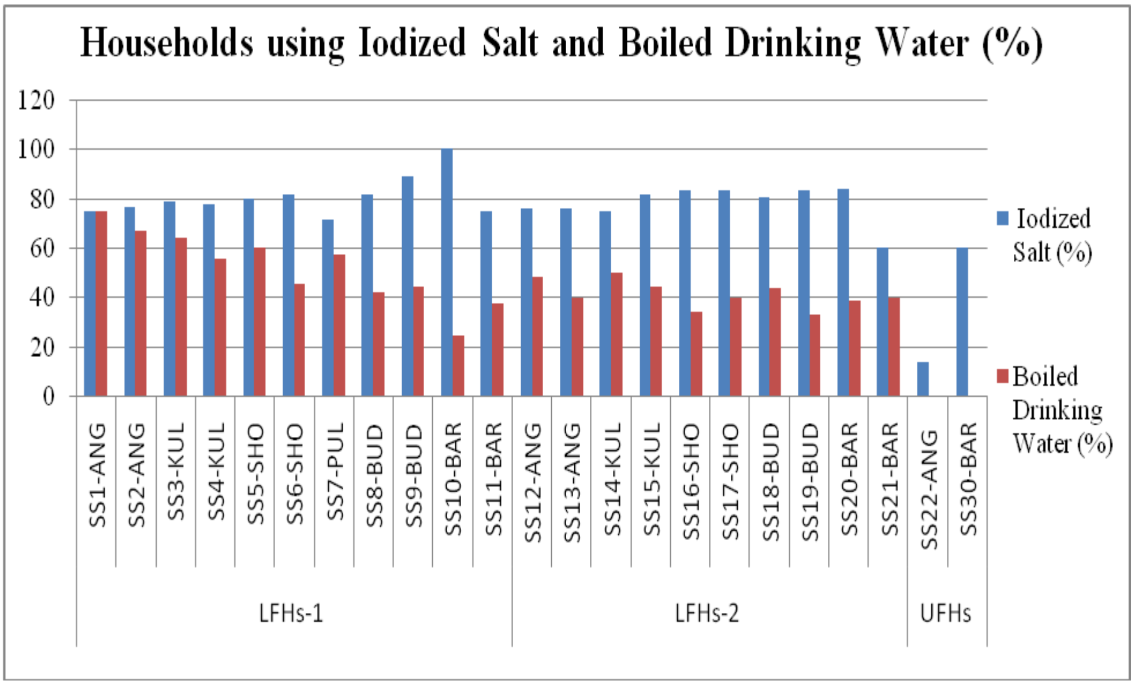


Fig. 5.2.3

Table 5.2.10: Shapiro-Wilk's Normality Test in one-way ANOVA: Households using Iodized Salt and Boiled Drinking Water (%)

	Zones	Statistic	df	Sig. (p-value)
Households using Iodized Salt (%)	LFHs-1	1.000	3	1.000
	LFHs-2	1.000	3	1.000
	UFHs	1.000	3	1.000
Households using Boiled Drinking Water (%)	LFHs-1	1.000	3	1.000
	LFHs-2	1.000	3	1.000
	UFHs	*	3	*

*Constant

Table 5.2.11: Levene's Test of Homogeneity of Variances in one-way ANOVA: Households using Iodized Salt and Boiled Drinking Water (%)

	Levene Statistic	df1	df2	Sig. (p-value)
Households using Iodized Salt (%)	0.0001	2	6	1.000
Households using Boiled Drinking Water (%)	2.007	2	6	0.215

Table 5.2.12: One-way ANOVA and Tukey post-hoc Tests: Households using Iodized Salt and Boiled Drinking Water (%)

		df	F	Sig. (p-value)
Households using Iodized Salt (%)	Between altitudinal zones	2	1.761	0.0001
	Within altitudinal zones	6		
	Total	8		
	LFHs-1 Vs LFHs-2	-	-	0.068
	LFHs-1 Vs UFHs	-	-	0.0001
	LFHs-2 Vs UFHs	-	-	0.0001
Households using Boiled Drinking Water (%)	Between altitudinal zones	2	2.929	0.0001
	Within altitudinal zones	6		
	Total	8		
	LFHs-1 Vs LFHs-2	-	-	0.0001
	LFHs-1 Vs UFHs	-	-	0.0001
	LFHs-2 Vs UFHs	-	-	0.0001

The mean difference is significant at the 0.05 level.

Table 5.2.13: Shapiro-Wilk's Normality Test in Independent Samples t-Test: Households using Iodized Salt and Boiled Drinking Water (%)

	Zones	Statistic	df	Sig. (p-value)
Households using Iodized Salt (%)	LFHs	1.000	3	1.000
	UFHs	1.000	3	1.000
Households using Boiled Drinking Water (%)	LFHs	1.000	3	1.000
	UFHs	*	3	*

*Constant

Table 5.2.14: Levene's Test for Equality of Variances in Independent Samples t-Test: Households using Iodized Salt and Boiled Drinking Water (%)

	F	Sig. (p-value)
Households using Iodized Salt (%)	0.0001	1.000
Households using Boiled Drinking Water (%)	4.000	0.116

Table 5.2.15: Independent Samples t-Test for Equality of Means: Households using Iodized Salt and Boiled Drinking Water (%))

	t	df	Sig. (2-tailed)
Households using Iodized Salt (%)			
Equal variances assumed	51.403	4	0.0001
Equal variances not assumed (Welch t-test)	51.403	4.000	0.0001
Households using Boiled Drinking Water (%)			
Equal variances assumed	78.920	4	0.0001
Equal variances not assumed (Welch t-test)	78.920	2.000	0.0001

The mean difference is significant at the 0.05 level.

5.2.5. Households with Different Levels of Income

The income status of the people has a close relationship with the choice of diet and hence human health. The low income status people mostly rely on low cost vegetarian foods and seldom use the non-vegetarian foods. Since, it has already been discussed that diet has a great role in the human health. The financially poor people having low per capita income hardly afford essential trace element rich non-vegetarian foods such as sea foods, meat, dairy products and the like and costly vegetarian foods (dry foods). They are forced to rely on essential trace element deficient locally cultivated foods.

From the Table 5.2.16, it is clear that about 15.71%, 36.52% and 47.77% households in the study area have low (Rs. <5, 000 month^{-1}), medium (Rs. 5, 000-10, 000 month^{-1}) and high (Rs. >10, 000 month^{-1}) income status respectively. The percentage of people in low, medium and high income groups changes with altitude from LFHs to UFHs from 15.26% to 26.3%, 36.51% to 36.8% and 48.23% to 36.9% respectively. In low and medium income groups, it increases with altitude while as in high income group decrease in percentage of people has been recorded. In the LFHs-1, the low and high income people record increase in percentage of people falling under respective groups with altitude from LFHs-1 to LFHs-2 from 15.17% to 15.33% and 46.63% to 49.27% respectively. While as, the percentage of people falling in medium income group showed a decrease with altitude from LFHs-1 to LFHs-2 from 38.20% to 35.40% respectively.

The analysis of Shapiro-Wilk's Normality test revealed that data pertaining to households in low income group was normally distributed for all the altitudinal zones (Table 5.2.17) and that there was homogeneity of variances as assessed by Levenes's test for Homogeneity of Variances (Table 5.2.18). Therefore, one-way ANOVA and Tukey post-hoc tests were run on the data. There was a statistically significant difference in the average of households in low income group between and within the altitudinal zones as determined by one-way ANOVA ($F_{2, 6}$ =63.441, p=0.0001) at significance level of 0.05 as shown in Table 5.2.19. A Tukey post-hoc multiple comparison test also revealed significant variation between LFHs-1 and UFHs (p=0.0001), and LFHs-2 and UFHs (p=0.0001) except LFHs-1 and LFHs-2 (p=0.992) (Table 5.2.19).

The Shapiro-Wilk's Normality test revealed that the data pertaining to households in low income group was normally distributed for both the altitudinal zones (Table 5.2.20) and that there was homogeneity of variances as assessed by Levenes's test for Equality of Variances (Table 5.2.21). Therefore, Independent Samples t-Test while assuming equal variances was employed to analyze the data. A statistically significant difference was revealed in the mean households in low income group between the altitudinal zones (LFHs and UFHs) (t_4=-9.615, p=0.001) at the significance level of 0.05 as shown in Table 5.2.22.

Table 5.2.16: Households with Different Levels of Income (Rs/month)

Macro Region	Micro Region	Sample Villages	Number of Households Surveyed (100%)	Average Family Size (numbers)	Households (%) with Different Income Levels		
					Low (Rs/month) (<5, 000)	Medium (Rs/month) (5, 000-10, 000)	High (Rs/month) (>10, 000)
LFHs	LFHs-1	SS1-ANG	08	6	2 (25.0)	4 (50.0)	2 (25.0)
		SS2-ANG	52	7	8 (15.4)	24 (46.1)	20 (38.5)
		SS3-KUL	14	6	3 (21.4)	6 (42.9)	5 (35.7)
		SS4-KUL	09	5	2 (22.2)	3 (33.3)	4 (44.5)
		SS5-SHO	05	6	1 (20.0)	1 (20.0)	3 (60.0)
		SS6-SHO	22	7	3 (13.6)	9 (40.0)	10 (45.4)
		SS7-PUL	14	6	2 (14.3)	6 (42.8)	6 (42.9)
		SS8-BUD	33	6	3 (9.1)	9 (27.3)	21 (63.6)
		SS9-BUD	09	6	2 (22.2)	2 (22.2)	5 (55.6)
		SS10-BAR	04	7	0 (0.0)	1 (25.0)	3 (75.0)
		SS11-BAR	08	5	1 (12.5)	3 (37.5)	4 (50.0)
	Total		**178**	**6.2**	**27 (15.17)**	**68 (38.20)**	**83 (46.63)**
	LFHs-2	SS12-ANG	29	7	6 (20.7)	12 (41.4)	11 (37.9)
		SS13-ANG	25	6	4 (16.0)	10 (40.0)	11 (44.0)
		SS14-KUL	08	6	1 (12.5)	3 (37.5)	4 (50.0)
		SS15-KUL	27	7	4 (14.8)	9 (33.4)	14 (51.8)
		SS16-SHO	61	5	8 (13.1)	20 (32.8)	33 (54.1)
		SS17-SHO	30	8	5 (16.6)	11 (36.7)	14 (46.7)
		SS18-BUD	52	5	8 (15.4)	19 (36.5)	25 (48.1)
		SS19-BUD	06	6	1 (16.7)	2 (33.3)	3 (50.0)
		SS20-BAR	31	7	4 (12.9)	10 (32.3)	17 (54.8)
		SS21-BAR	05	7	1 (20.0)	1 (20.0)	3 (60.0)
	Total		**274**	**6.4**	**42 (15.33)**	**97 (35.40)**	**135 (49.27)**
Total			**452**	**6.3**	**69 (15.26)**	**165 (36.51)**	**218 (48.23)**
UFHs	UFHs	SS22-ANG	14	7	4 (28.6)	6 (42.8)	4 (28.6)
		SS30-BAR	05	8	1 (20.0)	1 (20.0)	3 (60.0)
	Total		**19**	**7.5**	**5 (26.3)**	**7 (36.8)**	**7 (36.9)**
Grand Total			**471**	**6.9**	**74 (15.71)**	**172 (36.52)**	**225 (47.77)**

Source: Sample Survey, 2013

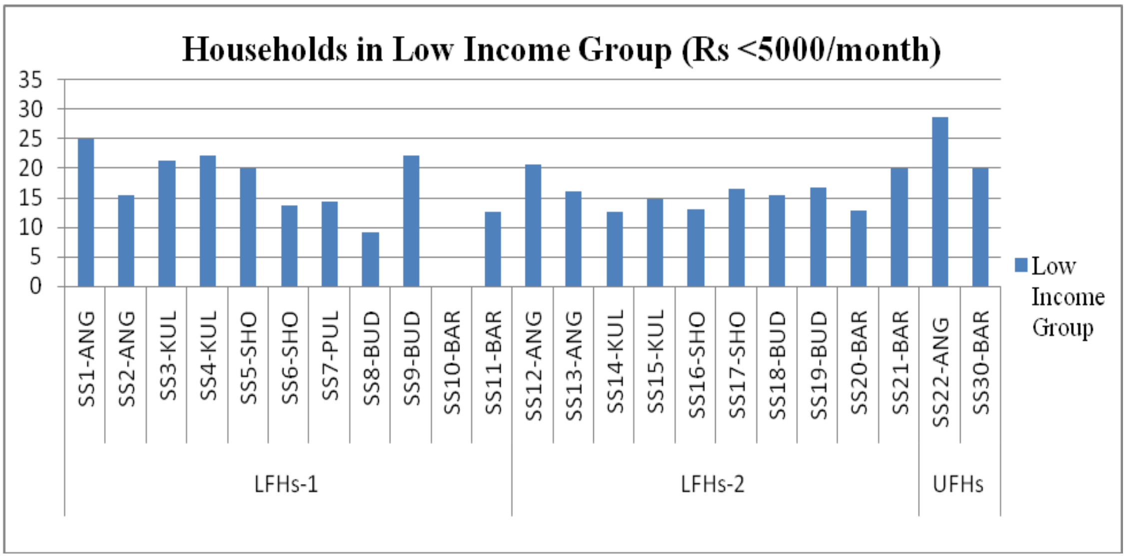


Fig. 5.2.4

Table 5.2.17: Shapiro-Wilk's Normality Test in one-way ANOVA: Households in Low Income Group (Rs <5000/month)

	Zones	Statistic	df	Sig. (p-value)
Households in Low Income Group (Rs <5000/month)	LFHs-1	1.000	3	1.000
	LFHs-2	1.000	3	1.000
	UFHs	1.000	3	1.000

Table 5.2.18: Levene's Test of Homogeneity of Variances in one-way ANOVA: Households in Low Income Group (Rs <5000/month)

	Levene Statistic	df1	df2	Sig. (p-value)
Households in Low Income Group (Rs <5000/month)	0.010	2	6	0.990

Table 5.2.19: One-way ANOVA and Tukey post-hoc Tests: Households in Low Income Group (Rs <5000/month)

		df	F	Sig. (p-value)
Households in Low Income Group (Rs <5000/month)	Between altitudinal zones	2	63.441	0.0001
	Within altitudinal zones	6		
	Total	8		
	LFHs-1 Vs LFHs-2	-	-	0.992
	LFHs-1 Vs UFHs	-	-	0.0001
	LFHs-2 Vs UFHs	-	-	0.0001

The mean difference is significant at the 0.05 level.

Table 5.2.20: Shapiro-Wilk's Normality Test in Independent Samples t-Test: Households in Low Income Group (Rs <5000/month)

	Zones	Statistic	df	Sig. (p-value)
Households in Low Income Group (Rs <5000/month)	LFHs	1.000	3	1.000
	UFHs	1.000	3	1.000

Table 5.2.21: Levene's Test for Equality of Variances in Independent Samples t-Test: Households in Low Income Group (Rs <5000/month)

	F	Sig. (p-value)
Households in Low Income Group (Rs <5000/month)	0.015	0.910

Table 5.2.22: Independent Samples t-Test for Equality of Means: Households in Low Income Group (Rs <5000/month)

	t	df	Sig. (2-tailed)
Households in Low Income Group (Rs <5000/month)			
Equal variances assumed	-9.615	4	0.001
Equal variances not assumed (Welch t-test)	-9.615	3.971	0.001

The mean difference is significant at the 0.05 level.

5.2.6. Use of Essential Trace Element Rich Fertilizers

Essential trace elements could be added to fertilizers to inject them in to the food chain. But, during the field survey, it was seen and investigated that the people made no use of essential trace element such as copper, zinc and iodine rich fertilizers. It may be because of the lack of knowledge about these fertilizers. The fertilizers such as zinc sulphate and copper sulphate are not used. The common fertilizers used are urea, potassium sulphate, diammonium phosphate and urea ammonium phosphate.

5.3. PREVALENCE OF ESSENTIAL TRACE ELEMENT RELATED DISORDERS

The essential trace elements have a crucial and important role in the survival of life and maintenance of good health. Human health is determined and conditioned to a great extent by the essential trace elements. So, whenever there is deficiency or toxicity of these elements in the human body, there occurs a series of health ailments. But, the deficiency of these elements in human body occurs only when there is deficiency of them in their diet because diet is the main source of these elements for humans. The present study revealed that the people suffer only from trace element deficiency diseases in the area. Therefore, the prevalence of essential trace element deficiency diseases would be discussed in the following pages.

5.3.1. Prevalence of Essential Trace Element Related Disorders in Lower Foot Hill Settlements-1 (LFHs-1)

In the LFHs-1, 8.87% people suffer from thyroid disorders (Table 5.3.1 figure 5.3.1). The highest (14.29%) and lowest (0.00%) percentage prevalence of the disease was found in SS1-ANG and SS10-BAR respectively. In this sub-zone, people had about 57.25% dependence on local foods (Table 5.2.1). About 75.84% people use non-favorable methods of cooking (Table 5.2.8).

About 1.70% people among the total population surveyed were found to be suffering from bone and nerve disorders (Table 5.3.2 and figure 5.3.2). In this sub-zone, people had about 57.25% dependence on local foods (Table 5.2.1). About 75.84% people use non-favorable methods of cooking (Table 5.2.8). The highest prevalence of 3.8% of the disease was revealed in SS3-KUL in LFHs-1 and lowest of 00% in SS5-SHO, SS7-PUL, SS9-BUD, and SS10-BAR.

About 1.70% people among the total population surveyed were found to be suffering from diabetes (Table 5.3.3 and figure 5.3.3). In the area, people had about 57.25% dependence on local foods (Table 5.2.1). About 75.84% people use non-favorable methods of cooking (Table 5.2.8). The highest prevalence of 6.00% of this disease was found in SS9-BUD and lowest prevalence of 0.00% in SS1-ANG, SS4-KUL, SS5-SHO, SS8-BUD and SS10-BAR.

Table 5.3.1: Prevalence of Thyroid Disorders

Macro Region	Micro Region	Sample Villages	No. of Persons Surveyed	Number of Persons Suffering From Thyroid Disorders (% to total persons surveyed)	
				Total	%
LFHs	LFHs-1	SS1-ANG	28	4	14.29
		SS2-ANG	230	26	11.30
		SS3-KUL	53	5	9.43
		SS4-KUL	40	4	10.00
		SS5-SHO	24	2	8.33
		SS6-SHO	92	6	6.52
		SS7-PUL	76	8	10.53
		SS8-BUD	165	11	6.67
		SS9-BUD	50	4	8.00
		SS10-BAR	22	0	0.00
		SS11-BAR	43	3	6.98
	Total		**823**	**73**	**8.87**
		SS12-ANG	110	12	10.91
		SS13-ANG	91	9	9.89
		SS14-KUL	40	4	10.00
		SS15-KUL	131	10	7.63
		SS16-SHO	330	20	6.06
		SS17-SHO	170	11	6.47
		SS18-BUD	270	21	7.78
		SS19-BUD	33	3	9.09
		SS20-BAR	160	13	8.13
		SS21-BAR	28	2	7.14
	Total		**1363**	**105**	**7.70**
Total			**2186**	**178**	**8.14**
		SS22-ANG	63	11	17.46
		SS30-BAR	29	1	3.5
	Total		**92**	**12**	**13.04**
Total			**2278**	**190**	**8.34**

Source: Sample Survey, 2013

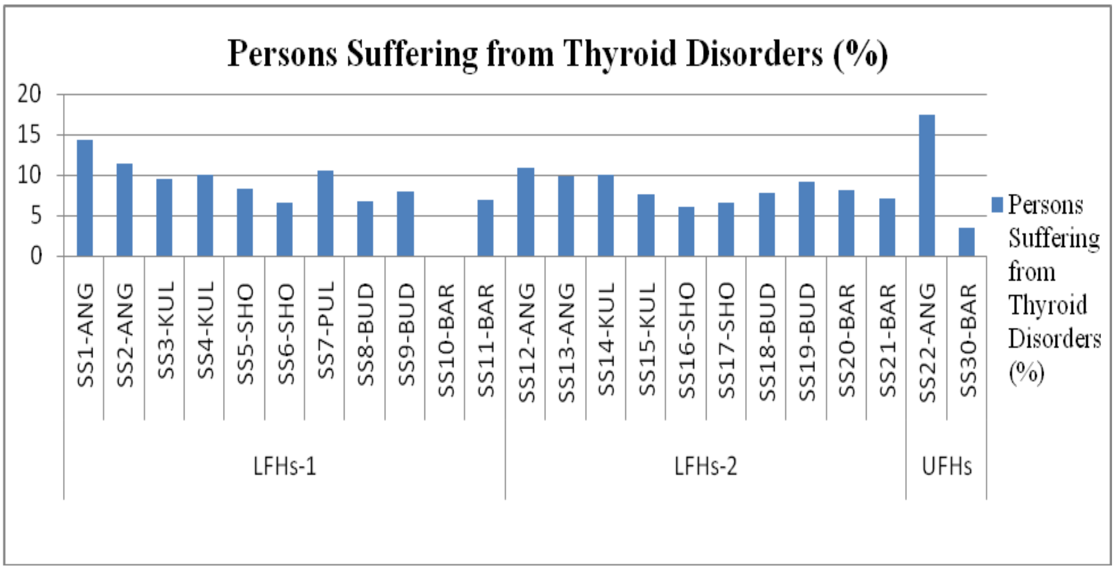


Fig. 5.3.1

Table 5.3.2: Prevalence of Bone and Nerve Ailments

Macro Region	Micro Region	Sample Villages	No. of Persons Surveyed	Number of Persons Suffering From Bone and Nerve Ailments (% to total persons surveyed)	
				Total	%
LFHs	LFHs-1	SS1-ANG	28	1	3.57
		SS2-ANG	230	3	1.30
		SS3-KUL	53	2	3.77
		SS4-KUL	40	1	2.50
		SS5-SHO	24	0	0.00
		SS6-SHO	92	2	2.17
		SS7-PUL	76	0	0.00
		SS8-BUD	165	4	2.42
		SS9-BUD	50	0	0.00
		SS10-BAR	22	0	0.00
		SS11-BAR	43	1	2.33
	Total		**823**	**14**	**1.70**
		SS12-ANG	110	3	2.73
		SS13-ANG	91	2	2.20
		SS14-KUL	40	1	2.50
		SS15-KUL	131	0	0.00
		SS16-SHO	330	7	2.12
		SS17-SHO	170	5	2.94
		SS18-BUD	270	9	3.33
		SS19-BUD	33	0	0.00
		SS20-BAR	160	3	1.88
		SS21-BAR	28	1	3.57
	Total		**1363**	**31**	**2.27**
Total				**45**	**2.06**
		SS22-ANG	63	0	0.00
		SS30-BAR	29	0	0.00
	Total		**92**	**0**	**0.00**
Total			**2278**	**45**	**1.98**

Source: Sample Survey, 2013

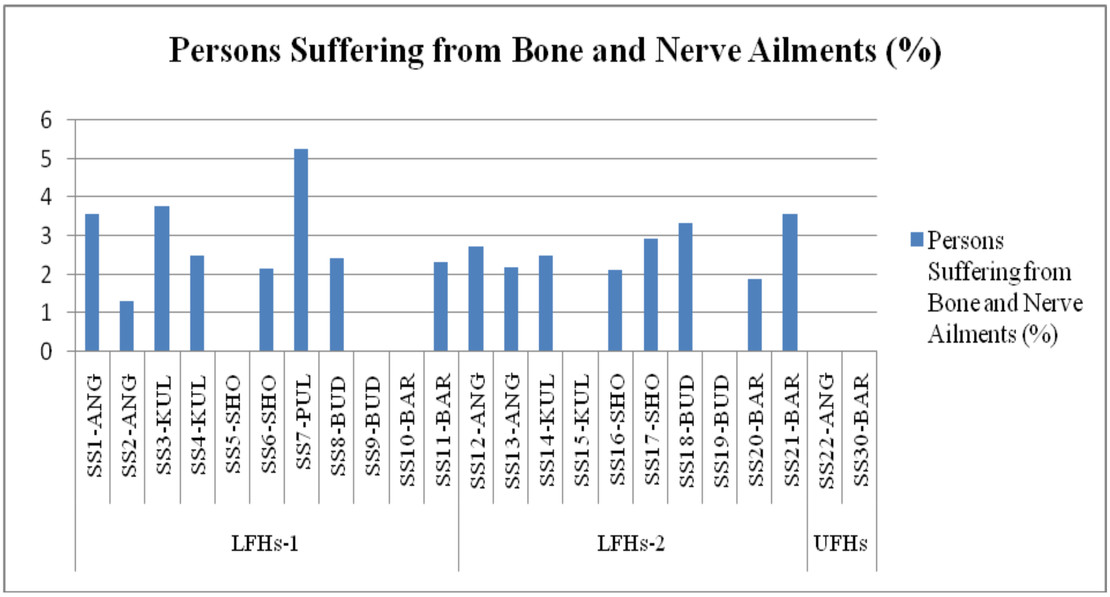


Fig. 5.3.2

Table 5.3.3: Prevalence of Diabetes

Macro Region	Micro Region	Sample Villages	No. of Persons Surveyed	Number of Persons Suffering From Diabetes (% to total persons surveyed)	
				Total	%
LFHs	LFHs-1	SS1-ANG	28	0	0.00
		SS2-ANG	230	3	1.30
		SS3-KUL	53	2	3.77
		SS4-KUL	40	0	0.00
		SS5-SHO	24	0	0.00
		SS6-SHO	92	3	3.26
		SS7-PUL	76	2	2.63
		SS8-BUD	165	0	0.00
		SS9-BUD	50	3	6.00
		SS10-BAR	22	0	0.00
		SS11-BAR	43	1	2.33
	Total		**823**	**14**	**1.70**
		SS12-ANG	110	3	2.73
		SS13-ANG	91	3	3.30
		SS14-KUL	40	0	0.00
		SS15-KUL	131	4	3.05
		SS16-SHO	330	0	0.00
		SS17-SHO	170	3	1.76
		SS18-BUD	270	6	2.22
		SS19-BUD	33	0	0.00
		SS20-BAR	160	3	1.88
		SS21-BAR	28	1	3.57
	Total		**1363**	**23**	**1.69**
Total				**37**	**1.69**
		SS22-ANG	63	1	1.59
		SS30-BAR	29	0	0.00
	Total		**92**	**1**	**1.09**
Total			**2278**	**38**	**1.67**

Source: Sample Survey, 2013

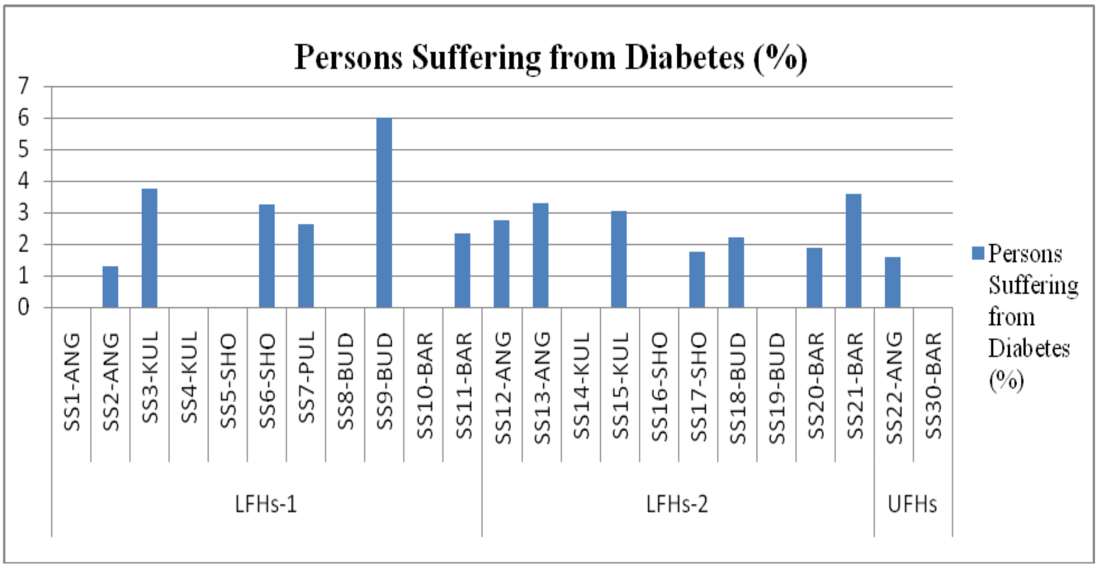


Fig. 5.3.3

5.3.2. Prevalence of Essential Trace Element Related Disorders in Lower Foot Hill Settlements-2 (LFHs-2)

In this micro-zone, out of 1363 persons surveyed, 105 (7.70%) persons were found suffering from thyroid disease. The highest (10.91%) and lowest (6.06%) percentage prevalence of the disease was found in SS12-ANG and SS16-SHO respectively. In this sub-zone, people had relatively low i.e., about 55.83% dependence on local foods than LFHs-1 (Table 5.2.1). About 65.69% households employ unfavorable methods of cooking (Table 5.2.8) and 60.87% households used to drink boiled water (Table 5.2.9).

About 2.27% people suffered from bone and nerve disorders (Table 5.3.2). In this sub-zone, people had relatively low i.e., about 55.83% dependence on local foods than LFHs-1 (Table 5.2.1). About 65.69% households employed inappropriate methods of cooking (Table 5.2.8). The extreme prevalence of the diseases was found as 3.57% in SS21-BAR and 0.00% in SS15-KUL and SS19-BUD in this micro-zone (Table 5.3.2). The dependence of the people on local foods was found as 56.00% and 55.80% (and 52.70%) in the former and latter sample villages respectively. In the former and latter sample villages, the percentages of households employing inappropriate cooking methods were found as 80.00% and 70.40% (and 66.70%) respectively. The income status of the households in the low income group also varied from SS21-BAR to SS15-KUL (SS19-BUD) from 20.00% to 14.80% (16.70%) respectively.

In this micro-zone, about 1.69% people suffered from diabetes (Table 5.3.3). In this sub-zone, people had relatively low i.e., about 55.83% dependence on local foods than LFHs-1 (Table 5.2.1). About 65.69% households employed unfavorable methods of cooking (Table 5.2.8). The highest and lowest prevalence of diabetes was found as 3.60% and 00% in SS21-BAR and SS14-KUL, SS16-SHO and SS19-BUD respectively in this micro-zone. The dependence of the people on local foods was found as 56.00% and 50.10% to 57.40% in the former and latter sample villages respectively (Table 5.2.1). In the former and latter sample villages, the percentages of households employing unfavorable cooking methods were found as 80.00% and 49.20% to 75.00% respectively (Table 5.2.8).

Summing up, in the LFHs, out of 2186 persons surveyed, 178 (8.14%) were suffering from thyroid disorders (Table 5.3.1). Within the LFHs i.e., at micro-zonal level, the percentage of people suffering from this disease varied rather decreased from LFHs-1 to LFHS-2 from 8.87% to 7.70% respectively with little variations in percentage prevalence of people suffering from thyroid with respect to age-sex groups. It is because of several factors as analyzed in tables 5.2.1, 5.2.8, 5.2.9 and 5.2.16. The dependence of people on local foods decreased from LFHs-1 to LFHs-2 from 57.25% to 55.83% respectively (Table 5.2.1). The percentage of households using nutrient loss causing cooking methods decreased from LFHs-1 to LFHs-2 from 75.84% to 65.69% respectively (Table 5.2.8). A slight variation had been found in the total income status of the households from LFHs-1 to LFHs-2 (Table 5.2.16). The highest (14.29%) and lowest (0.00%) percentage prevalence of the disease was found in SS1-ANG and SS10-BAR respectively.

About 2.06% people were indentified to be suffering from the ailments in the LFHs. Within the LFHs, the percentage prevalence of the diseases increased from LFHs-1 to LFHs-2 from 1.70% to 2.27% respectively. It is because of several factors as analyzed in tables 5.2.1, 5.2.8 and 5.2.16. The dependence of people on local foods decreased from LFHs-1 to LFHs-2 from 57.25% to 55.83% respectively. The percentage of households using nutrient loss causing cooking methods decreased from LFHs-1 to LFHs-2 from 75.84% to 65.69% respectively. A slight variation had been found in the total income status of the households from LFHs-1 to LFHs-2. The highest prevalence of 3.8% of the disease was revealed in SS3-KUL in LFHs-1 and lowest of 00% in SS5-SHO, SS7-PUL, SS9-BUD, and SS10-BAR in LFHs-1 and SS15-KUL and SS19-BUD in LFHs-2. In the former sample village, the dependence of people on local foods was found as 62.00% and percentage of households employing unfavorable cooking methods as 85.7%. While as in the latter sample villages, the dependence of people on local foods varied from 47.30-61.10% and percentage of households employing unfavorable cooking methods varied from 25.00-78.60%.

About 1.69% people were found to be suffering from diabetes in the LFHs. Within the LFHs, the prevalence of the disease decreased from LFHs-1 to LFHs-2 from 1.70% to 1.69% respectively. It is because of several factors as analyzed in tables 5.2.1, 5.2.8 and 5.2.16. The dependence of people on local foods decreased from LFHs-1 to LFHs-2 from 57.25% to 55.83% respectively. The percentage of households using nutrient loss causing cooking methods decreased from LFHs-1 to LFHs-2 from 75.84% to 65.69% respectively. A slight variation had been found in the total income status of the households from LFHs-1 to LFHs-2. The highest prevalence of 6.00% of this disease was found in SS9-BUD in LFHs-1 and lowest prevalence of 0.00% in SS1-ANG, SS4-KUL, SS5-SHO, SS8-BUD, SS10-BAR in LFHs-1 and SS14-KUL, SS16-SHO, and SS19-BUD in LFHs-2.

5.3.3. Prevalence of Essential Trace Element Related Disorders in Upper Foot Hill Settlements (UFHs)

In UFH macro-zone, 13.04% people suffered from thyroid disorders. There are only two sample villages and percentage prevalence of thyroid varied from 17.46% to 3.5% from SS22-ANG to SS30-BAR respectively. The highest percentage prevalence of the disease in this zone could be attributed to the highest (71.25%) dependence of the people on local nutrient deficit foods and very less of iodized salt (Tables 5.2.1 and 5.2.9). Only 26.32% households use iodized salt.

In this zone, no person was found to be suffering from the bone and nerve disorders and the probable reasons are same as given above.

In this zone, about 1.09% people were found to be suffering from diabetes (Table 5.3.3). The dependence of people on local foods was found as 71.25% (Table 5.2.1) and about 68.42% households employed unfavorable cooking methods (Table 5.2.8). Though there was highest dependence of people on local foods in this zone, the highest prevalence of diabetes was not found. Since there were only two sample villages taken, the highest and lowest prevalence of diabetes in them was found as 1.6% and 00% in SS22-ANG and SS30-BAR respectively. In the former sample village, about 85.7% households employed inappropriate cooking methods as compared to latter where 20.0% households employed these cooking methods (Table 5.2.8).

Therefore, it was found that out of total population surveyed in the whole foot hill region, about 11.98% people (Table 5.3.4 and figure 5.3.4) suffered from different essential trace element deficiency diseases for there is deficiency of essential trace elements in the soil and water (Tables 5.1.1 and 5.1.2). The percentage of people suffering from some essential trace element deficiency related ailments increased from 11.89% to 14.13% from LFHs to UFHs. At the sample village level, the highest percentage prevalence of 19.05% was revealed in SS22-ANG in UFHs and lowest prevalence of 0.00% in SS10-BAR in LFHs (LFHs-1). The prevalence can be ascribed to the deficiency of I, Cu and Zn in the soils and drinking waters (Tables 5.1.1 and 5.1.2). But, the variations at the sample village level or at macro- or micro-zonal level can be more attributed to the socio-economic determinants such as dependence of people on local foods, inappropriate cooking methods, more use of boiled drinking water, and disadvantageous income levels that is clear from tables 5.2.1, 5.2.8, 5.2.9 and 5.2.16. From table 5.2.1, it is clear that the people in the foot hill settlements have about 63.89% dependence on local foods. About 69.64% households used unfavorable deep long period cooking methods involving high temperatures and discarding water (Table 5.2.8). About 42.46% households used boiled drinking water (Table 5.2.9). The income level is the driving force that determines the food composition and hence health of the people. About 52.23% households were found with inadequate income (Table 5.2.16).

Table 5.3.4: Prevalence of Essential Trace Element Deficiency Diseases

Macro Region	Micro Region	Sample Villages	No. of Persons Surveyed	Number of Persons Suffering From ETEDDs* (% to total persons surveyed)	
				Total	%
LFHs	LFHs-1	SS1-ANG	28	5	17.86
		SS2-ANG	230	32	13.91
		SS3-KUL	53	9	16.98
		SS4-KUL	40	5	12.50
		SS5-SHO	24	2	8.33
		SS6-SHO	92	11	11.96
		SS7-PUL	76	10	13.16
		SS8-BUD	165	15	9.09
		SS9-BUD	50	7	14.00
		SS10-BAR	22	0	0.00
		SS11-BAR	43	5	11.63
	Total		**823**	**101**	**12.27**
		SS12-ANG	110	18	16.36
		SS13-ANG	91	14	15.38
		SS14-KUL	40	5	12.50
		SS15-KUL	131	14	10.69
		SS16-SHO	330	27	8.18
		SS17-SHO	170	19	11.18
		SS18-BUD	270	36	13.33
		SS19-BUD	33	3	9.09
		SS20-BAR	160	19	11.88
		SS21-BAR	28	4	14.29
	Total		**1363**	**159**	**11.66**
Total				**260**	**11.89**
		SS22-ANG	63	12	19.05
		SS30-BAR	29	1	3.45
	Total		**92**	**13**	**14.13**
Total			**2278**	**273**	**11.98**

Source: Sample Survey, 2013

*ETEDDs= Essential Trace Element Deficiency Diseases

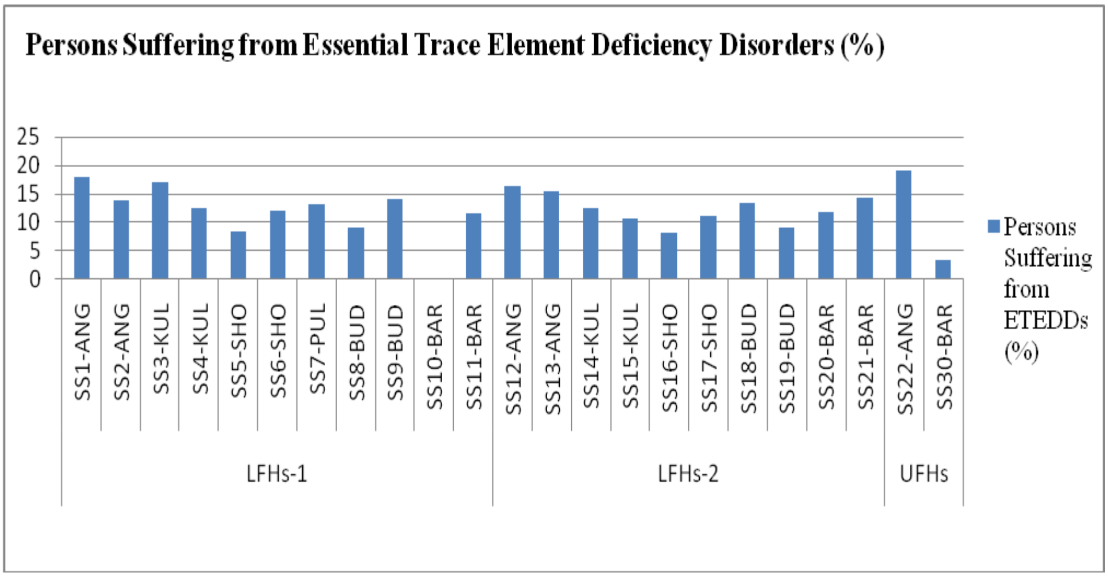


Fig. 5.3.4

The prevalence of essential trace element deficiency disorders is explained as:

From the study, it was noticed that about 8.34% were found suffering from thyroid disorders in the area with no significant variation between sex groups but significant variation between age groups (Table 5.3.1 and figure 5.3.1). At macro-altitudinal zone level, there was found increase in the percentage prevalence of thyroid cases from LFHs to UFHs from 8.14% to 13.04% respectively. The highest (17.46%) and lowest (0.00%) percentage of people suffering from thyroid ailments in the area were found in SS22-ANG in UFHs and SS10-BAR in LFHs (LFHs-1) respectively. The very low concentration of iodine in the soils and drinking waters (Table 5.1.1 and 5.1.2) might be responsible for the prevalence of thyroid disorders. The variation in the percentage of people suffering from thyroid disorders at sample village or macro-zonal level can be attributed to variations in the dependence of people on local iodine deficit food items, cooking methods, use of iodized salt and boiled drinking water, and low income levels as is clear from tables 5.2.1, 5.2.8, 5.2.9 and 5.2.16.

Only 45 persons (1.98%) out of the 2278 persons surveyed were found suffering from bone and nerve ailments (Table 5.3.2 and figure 5.3.2). Though, the people had greater dependence on vegetarian foods, but still the food is not enough rich to supply the required amount of copper to the human body. Therefore, the prevalence of the disease could be attributed to the deficiency of copper in the soil and water and non-availability of copper rich vegetarian varieties. The percentage prevalence of such ailments varies from LFHs to UFHs from 2.06% to 0.00% respectively. The soils and drinking waters of the area are deficient in copper (Table 5.1.1 and 5.1.2). Moreover, it could be attributed to some factors as analyzed in tables 5.2.1, 5.2.8 and 5.2.16. It was found that the dependence of people on local foods as 63.89% (Table 5.2.1). About 69.64% households used unfavorable cooking methods (Table 5.2.8). Again, 15.71% and 36.52% households were in the low and medium income groups respectively (Table 5.2.16). No person was found to be suffering from such diseases out of 92 persons surveyed in the UFH macro zone. The zero prevalence of the disease in UFH region might be because of certain reasons. One, the people of the area were absolutely rural in character and rarely maintain prescription records. Second, the people seldom consult specialist doctors who could recommend them for proper examination and testing. The highest prevalence of 3.8% of the disease was revealed in SS3-KUL in LFHs-1 and lowest of 00% in SS5-SHO, SS7-PUL, SS9-BUD, SS10-BAR, SS15-KUL and SS19-BUD in LFHs and SS22-ANG and SS30-BAR in UFHs. In the former sample village, the dependence of people on local foods was food as 62.00% and percentage of households employing unfavorable cooking methods as 85.7%. While as in the latter sample villages, the dependence of people on local foods varied from 47.30-75.00% and percentage of households employing unfavorable cooking methods as 20.00-85.70%.

In the area under study, about 1.67% people were found to be suffering from diabetes (i.e., diabetes mellitus-II) (Table 5.3.3 and figure 5.3.3). The occurrence of diabetes can be referred to the deficiency of zinc in the soil and water systems of the area (Table 5.1.1 and 5.1.2). Moreover, human beings derive this nutrient from the food especially the non-vegetarian diet. The percentage prevalence of diabetes in the foot hill settlements decreased from LFHs to UFHs from 1.69% to 1.09% respectively. It could also be attributed to several factors as highlighted in tables 5.2.1, 5.2.8, 5.2.9 and 5.2.16. The dependence of people on local foods was found as 63.89% with variation from LFHs to UFHs from 56.54% to 71.25% respectively (Table 5.2.1). It seems that greater prevalence of diabetes should be in UFH macro-zone, but it is not so. It could be because; in the UFHs, one, there is least maintenance of prescription records, second, the people did not consult specialists and third there is relatively less employment of unfavorable cooking methods. About 69.64% households employed bad cooking methods with decrease from LFHs to UFHs from 69.69% to 68.42% respectively (Table 5.2.8). In this zone, the highest prevalence of 6.00% of this disease was found in SS9-BUD in LFHs and lowest prevalence of 0.00% in SS1-ANG, SS4-KUL, SS5-SHO, SS8-BUD, SS10-BAR, SS14-KUL, SS16-SHO, and SS19-BUD in LFHs and SS30-BAR in UFHs. In SS9-BUD, the dependence of people on zinc deficient local foods was 57.10%. About 77.8% households employed unfavorable cooking methods in SS9-BUD (Table 5.2.8).

5.4. IDENTIFICATION OF THE ESSENTIAL TRACE ELEMENT DISEASE RISK ZONES

The identification and categorization of the essential trace element disease risk zones is a very tedious task. It is the first and foremost step in the suitable planning strategy that involves everything that is connected with the process of minimizing the magnitude of essential trace element related health disorders in the human beings in the area.

5.4.1. Computation of Composite Score

In the present study, essential trace element deficiency related disease risk area identification was based on three main essential factors (Table 5.4.1) which are as:

1. Concentration of essential trace elements in soils (I, Cu, Zn)

2. Concentration of essential trace elements in drinking waters (I, Cu, Zn)

3. Dependence on non-local Food Products (%)

Composite score method was used for identification of essential trace element disease risk zones. The two main steps involved in the computation of composite score are the removal of biasness of scale and assignment of weights to the variables. The biasness of scale was removed through the method of standardization (Mahmood, 1986) (Table 5.4.2). In the process of assignment of weights, the weights were determined subjectively. The values of 1, 2 and 3 were assigned as weights to the variables of dependence on non-local food products (%), concentration of essential trace elements in soils (I, Cu, Zn) and concentration of essential trace elements in drinking waters (I, Cu, Zn) respectively. The composite score was calculated as

$$\sum_{i=1}^{n} (\mathbf{SViSj} \times \mathbf{WiSj})$$

Where, SV_iSj= Standardized Variables (i=1 to 7) at sample site j (j =1 to 23) and

W_iSj = Weights given to Standardized variables (i=1 to 7) at sample site j.

The computation of composite score is shown in table 5.4.3.

5.4.2. Essential Trace Element Disease Risk Zones

Sample villages along with altitudinal zone were then categorized into various categories of risks like very high, high, medium, low and very low for future planning strategy (Table 5.4.4 and Fig. 5.4.1). These categories of risk areas are described as under:

Very High Risk Areas

In this risk zone fall only two sample villages, Chachmolla, Narwaw and Bindoo Zalan Gam of LFHs-1 and Kundribal in UFHs. These sample villages recorded relatively lowest essential trace element concentrations in the soil and drinking waters than other sample villages (Table 5.1.1 and 5.1.2). Moreover, the people of these areas have more dependence on local foods (54.80% to 75.00%, Table 5.2.1).

High Risk Areas

Seven sample villages from all the altitudinal zones fall in high risk category. Bidder Hayat Pora and Awind Gund in LFHs-1, Hala Pora in LFHs-2 and Raing Mandoo in UFHs respectively fall in this risk zone. Though essential trace element contents in the soil and drinking water are relatively higher than some other sample villages (Table 5.1.1 and 5.1.2) but it is still inadequate to fulfill the human requirement. Moreover, the other factors such as relatively greater dependence on local foods (61.10% to 69.83%, Table 5.2.1) cause the problem of risk.

Medium Risk Areas

In this category of risk areas fall five sample villages of LFHs which include Chandergi, Sandho Shirmal and Raithan from LFHs-1 and Tala Pora and Gurweth Kalan from LFHs-2. In this zone, the soil and drinking water samples recorded inadequate concentration of essential trace elements (Table 5.1.1 and 5.1.2).

Additionally, these sample villages showed moderate dependence of 52.70% to 62.00% on local foods (Table 5.2.1).

Low Risk Areas

Seven sample villages fall in low risk category which are Tokal Pora, Mula Naru and Raj Pora Thandakasi in LFHs-1 and Takia Yousuf Shah, Halan, Katho Halan, Gaw Ran in LFHs-2. The samples of this zone record relatively high concentration of essential trace elements than others, (Table 5.1.1 and 5.1.2) though inadequate. These areas showed moderate dependence on local foods and relatively high dependence on market foods (Table 5.2.1) than in medium, high and very high risk zones.

Very Low Risk Areas

In UFHs and LFHs-1, no sample village showed very low risk of essential trace element deficiency disorders. In LFHs, three sample villages with lowest composite score ranging from 8.3087 to 14.2510 fall in very low risk areas. Namely, these are Kata Pora, Sedheve and Marg Bal in LFHs-2. These sample villages record relatively highest concentration of essential trace elements in their soils and drinking waters (Table 5.1.1 and 5.1.2).

Table 5.4.1: Variables (Raw Scores)

S. No.	Sample Village	Concentration of Trace Elements in Soil (mg kg^{-1})			Concentration of Trace Elements in Drinking Water (µg L^{-1})			Dependence on non-local Food Products (%)
		I (X_1)	Zn (X_2)	Cu (X_3)	I (X_4)	Zn (X_5)	Cu (X_6)	(X_7)
1	Bidder Hayat Pora	0.98	1.134	1.664	3.4	16	18	37.80
2	Bindoo Zalan Gam	1	0.798	2.27	2.6	25	12	43.50
3	Chandergi	1.5	1.861	3.012	3	30	15	38.00
4	Chachmolla	0.95	0.67	1.901	2.3	48	13	45.20
5	Narwaw	1.1	0.674	1.558	2.4	90	5	44.00
6	Sandho Shirmal	1.45	0.34	2.396	3.6	56	18	39.20
7	Awind Gund	1.22	0.901	2.023	3.5	35	15	38.90
8	Raithan	1.42	1.71	0.26	2.2	30	25	47.00
9	Mula Naru	1.56	1.654	3.002	4.1	45	14	42.90
10	Tokal Pora	1.62	1.56	3.021	2.5	40	26	52.70
11	Raj Pora Thandakasi	1.03	1.101	2.102	4.3	59	23	41.00
12	Hala Pora	1.23	1.332	1.558	3.9	75	12	30.17
13	Gaw Ran	0.97	0.734	1.654	4.2	217	12	43.00
14	Marg Bal	1.55	1.962	3.043	3.7	84	21	42.60
15	Halan	1.47	0.95	2.078	3.5	120	22	44.20
16	Sedheve	1.37	1.582	1.684	4.1	191	18	49.90
17	Katho Halan	1.02	1.176	4.45	4.4	19	18	44.50
18	Gurweth Kalan	1.36	0.5	2.396	3.6	132	12	45.00
19	Tala Pora	1.02	1.502	2.09	3.2	110	17	47.30
20	Kata Pora	1.65	1.75	3.956	3.6	115	18	51.00
21	Takia Yousuf Shah	1.53	1.102	2.985	3	124	20	44.00
22	Raing Mandoo	1.05	1.772	1.16	2.7	93	16	32.5
23	Kundribal	0.99	0.56	1.076	2.8	96	19	25.00
	Mean	1.26	1.19	2.23	3.33	80.43	16.91	42.15
	STDEV	0.25	0.49	0.94	0.68	53.41	4.85	6.48

Source: Based on Sample Analysis and Sample Survey, 2013

Table 5.4.2: Standardization of the Variables

Sample Village	Concentration of Trace Elements in Soil			Concentration of Trace Elements in Drinking Water			Dependence on non-local Food Products	$\sum_{i=1}^{n} SViSj$
	I (SV_1S_j)	Zn (SV_2S_j)	Cu (SV_3S_j)	I (SV_4S_j)	Zn (SV_5 S_j)	Cu (SV_6 S_j)	(SV_7 S_j)	
Bidder Hayat Pora	-1.120	-0.114	-0.602	0.225	0.103	-1.206	-0.671	-3.385
Bindoo Zalan Gam	-1.040	-0.800	0.043	-1.012	-1.074	-1.038	0.208	-4.713
Chandergi	0.960	1.369	0.832	-0.394	-0.485	-0.944	-0.640	0.698
Chachmolla	-1.240	-1.061	-0.350	-0.806	-1.515	-0.607	0.471	-5.108
Narwaw	-0.640	-1.053	-0.715	-2.456	-1.368	0.179	0.285	-5.768
Sandho Shirmal	0.760	-1.735	0.177	0.225	0.397	-0.457	-0.455	-1.088
Awind Gund	-0.160	-0.590	-0.220	-0.394	0.250	-0.851	-0.502	-2.467
Raithan	0.640	1.061	-2.096	1.668	-1.662	-0.944	0.748	-0.585
Mula Naru	1.200	0.947	0.821	-0.600	1.132	-0.663	0.116	2.953
Tokal Pora	1.440	0.755	0.841	1.874	-1.221	-0.757	1.628	4.560
Raj Pora Thandakasi	-0.920	-0.182	-0.136	1.256	1.426	-0.401	-0.177	0.866
Hala Pora	-0.120	0.290	-0.715	-1.012	0.838	-0.102	-1.849	-2.670
Gaw Ran	-1.160	-0.931	-0.613	-1.012	1.279	2.557	0.131	0.251
Marg Bal	1.160	1.576	0.865	0.843	0.544	0.067	0.069	5.124
Halan	0.840	-0.490	-0.162	1.049	0.250	0.741	0.316	2.544
Sedheve	0.440	0.800	-0.581	0.225	1.132	2.070	1.196	5.282
Katho Halan	-0.960	-0.029	2.362	0.225	1.574	-1.150	0.363	2.385
Gurweth Kalan	0.400	-1.408	0.177	-1.012	0.397	0.966	0.440	-0.040
Tala Pora	-0.960	0.637	-0.149	0.019	-0.191	0.554	0.795	0.705
Kata Pora	1.560	1.143	1.836	0.225	0.397	0.647	1.366	7.174
Takia Yousuf Shah	1.080	-0.180	0.803	0.637	-0.485	0.816	0.285	2.956
Raing Mandoo	-0.840	1.188	-1.138	-0.188	-0.926	0.235	-1.489	-3.158
Kundribal	-1.080	-1.286	-1.228	0.431	-0.779	0.292	-2.647	-6.297

Table 5.4.3: Computation of the Composite Score

Sample Village	Concentration of Trace Elements in Soil			Concentration of Trace Elements in Drinking Water			Dependence on non-local Food Products	$\sum_{i=1}^{n}$(SViSj×Wi Sj)
	I ($SV_1S_j \times W_1S_j$)	Zn ($SV_2S_j \times W_2S_j$)	Cu ($SV_3S_j \times W_3S_j$)	I ($SV_4S_j \times W_4S_j$)	Zn ($SV_5S_j \times W_5S_j$)	Cu ($SV_6S_j \times W_6S_j$)	($SV_7S_j \times W_7S_j$)	
Bidder Hayat Pora	-2.24	-0.228	-1.204	0.675	0.309	-3.618	-0.671	-6.977
Bindoo Zalan Gam	-2.08	-1.6	0.086	-3.036	-3.222	-3.114	0.208	-12.758
Chandergi	1.92	2.738	1.664	-1.182	-1.455	-2.832	-0.640	0.213
Chachmolla	-2.48	-2.122	-0.7	-2.418	-4.545	-1.821	0.471	-13.615
Narwaw	-1.28	-2.106	-1.43	-7.368	-4.104	0.537	0.285	-15.466
Sandho Shirmal	1.52	-3.47	0.354	0.675	1.191	-1.371	-0.455	-1.556
Awind Gund	-0.32	-1.18	-0.44	-1.182	0.75	-2.553	-0.502	-5.427
Raithan	1.28	2.122	-4.192	5.004	-4.986	-2.832	0.748	-2.856
Mula Naru	2.4	1.894	1.642	-1.8	3.396	-1.989	0.116	5.659
Tokal Pora	2.88	1.51	1.682	5.622	-3.663	-2.271	1.628	7.388
Raj Pora Thandakasi	-1.84	-0.364	-0.272	3.768	4.278	-1.203	-0.177	4.190
Hala Pora	-0.24	0.58	-1.43	-3.036	2.514	-0.306	-1.849	-3.767
Gaw Ran	-2.32	-1.862	-1.226	-3.036	3.837	7.671	0.131	3.195
Marg Bal	2.32	3.152	1.73	2.529	1.632	0.201	0.069	11.633
Halan	1.68	-0.98	-0.324	3.147	0.75	2.223	0.316	6.812
Sedheve	0.88	1.6	-1.162	0.675	3.396	6.21	1.196	12.795
Katho Halan	-1.92	-0.058	4.724	0.675	4.722	-3.45	0.363	5.056
Gurweth Kalan	0.8	-2.816	0.354	-3.036	1.191	2.898	0.440	-0.169
Tala Pora	-1.92	1.274	-0.298	0.057	-0.573	1.662	0.795	0.997
Kata Pora	3.12	2.286	3.672	0.675	1.191	1.941	1.366	14.251
Takia Yousuf Shah	2.16	-0.36	1.606	1.911	-1.455	2.448	0.285	6.595
Raing Mandoo	-1.68	2.376	-2.276	-0.564	-2.778	0.705	-1.489	-5.706
Kundribal	-2.16	-2.572	-2.456	1.293	-2.337	0.876	-2.647	-10.003

Table 5.4.4: Classification of Sample Villages into Five Risk Zones

Composite Score	Risk Zones	Lower Foot Hill Settlements (1, 800-2, 400 m AMSL)		Upper Foot Hill Settlements (2, 400-3, 000 m AMSL)
		LFHs-1 (1, 800-2, 100)	LFHs-2 (2, 100-2, 400)	
-14.4660 to -9.5226	Very High	Chachmolla, Narwaw Bindoo Zalan Gam,	-	Kundribal
-9.5226 to -3.5226	High	Bidder Hayat Pora, Awind Gund	Hala Pora	Raing Mandoo
-3.5226 to 2.3653	Medium	Chandergi Sandho Shirmal, Raithan,	Tala Pora, Gurweth Kalan	-
2.3653 to 8.3087	Low	Tokal Pora, Mula Naru, Raj Pora Thandakasi	Takia Yousuf Shah, Halan, Katho Halan, Gaw Ran	-
8.3087 to 14.2510	Very Low	-	Kata Pora, Sedheve, Marg Bal	-
NA	NA	Uninhabited Areas		

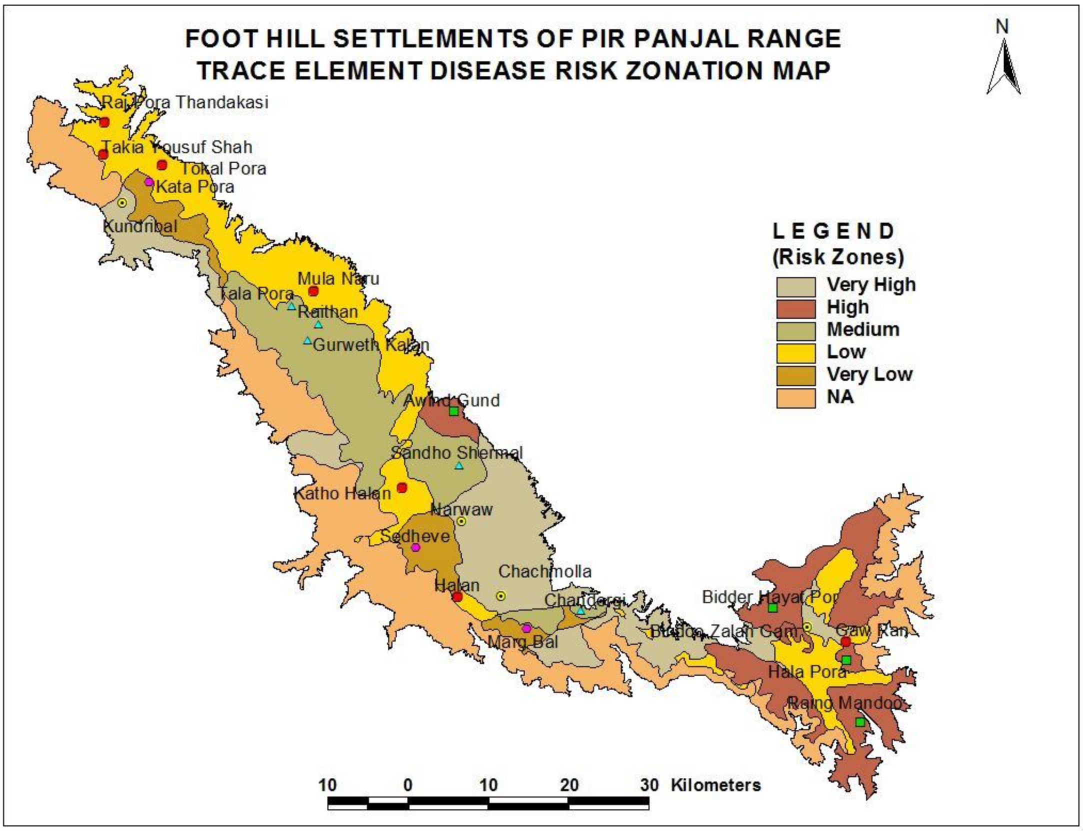


Fig. 5.4.1

CHAPTER-6

CONCLUSIONS, SUGGESTIONS AND PLANNING STRATEGY

The present research work provides an analysis of the status of essential trace elements in the soil and drinking water sources in the foot hill settlements of Pir Panjal range. Also, it provides an insight into the socio-economic character of the people and the prevalence of the essential trace element related deficiency disorders in the area. This section of the work highlights the conclusions of the work and suggestions for the same and planning strategy to minimize the problem of the booming prevalence of the essential trace element related deficiency disorders in the area.

6.1. CONCLUSIONS

The soils of the foot hills of Pir Panjal range in Kashmir valley were found deficient in essential trace elements. The deficiency of these elements was revealed to determine the human health in the area. The average iodine content in the soils of foot hill settlements was found as1.27 mg kg^{-1}. The total iodine content, pH and OM in the soil types varies from 0.90-1.65 mg kg^{-1}, 5.66-7.51 and 1.34-5.24% respectively. At altitudinal level, the mean iodine content decreased from 1.29 mg kg^{-1} to 1.24 mg kg^{-1} from LFHs to UFHs. The organic content in the soil was found as dominant determinant of iodine retention potential of soil. A very significant variation in data across altitudinal zones ($F_{2, 12}$ =57.67, p=0.0001) at significance level of 0.05 was revealed. The average iodine content in drinking waters was found as 3.2 µg L^{-1}. The iodine content varies from 2.2-4.4 µg L^{-1}. The data of concentration of iodine in drinking water samples showed significant variation across altitudinal zones ($F_{2, 12}$ =7.34, p=0.008).

The average copper concentration in the soils of the study area was revealed as 2.20 mg kg^{-1}. The mean copper concentration decreased with altitude from 2.34 mg kg^{-1} to 1.90 mg kg^{-1} from LFHs to UFHs with mean OM from 3.56% to 3.40%. The total copper concentration in soils at sample sites ranged from 0.26-4.45 mg kg^{-1}. The results are in conformity with the results of Nazif, *et al*. (2006) Arokiyaraj, *et al*. (2011) and Wani, *et al*. (2013). The organic matter and clay fraction in the soil were found as major factors determining copper content in the soil. Same results were reported by Karim, *et al*. (1976), Katyal and Vlek (1985) and Wani, *et al*. (2013) in terms of relationship of copper with OM and clay fraction. The data showed a very significant variation across altitudinal zones ($F_{2,12}$ =2.33, p=0.0001) at significance level of 0.05. The average concentration of copper in the drinking waters of the study area were found as 16.6 µg L^{-1} that is very less than acceptable limits. According to Bureau of Indian Standards (2009), the acceptable limit or required amount of copper in drinking water should be 50 µg L^{-1}. The results are almost same as reported by Jeelani (2010). No significant relationships were found between the drinking water variables.

The average zinc content in the soils of the study area was found as 1.179 mg kg^{-1} with average pH and OM of 6.82 and 3.51% respectively. The mean zinc concentration decreased with altitude from 1.190-1.157 mg kg^{-1} from LFHs to UFHs with mean OM from 3.56% to 3.40% respectively. The results were in line those of the results of Nazif, *et al*. (2006) Talikdar, *et al*. (2009), Mahashabde and Patel (2012) and Wani, *et al*. (2013). The zinc content at different sample sites showed a variation from one another with respect to variation in pH, OM and other soil characters. Same results were reported by Wani, *et al*. (2013) so far the relationship of zinc with OM, and pH is concerned. The zinc content, pH and OM varied from 0.500-1.962 mg kg^{-1}, 5.66-7.51 and 1.34-5.24% respectively. The data depicted a very significant variation across altitudinal zones ($F_{2, 12}$ =2.42, p=0.0001) at significance level of 0.05. The average zinc content in the drinking waters of the study area was found as 67.0 µg L^{-1} with mean pH of 7.62. The total human requirement of zinc varies from 10-15 mg $person^{-1}day^{-1}$. According to BIS (2009), the acceptable or required quantity of zinc in drinking water should be 5000 µg L^{-1}. So, the copper content in the drinking waters in the area is very less than the acceptable amounts in drinking water. The mean zinc content showed decrease from 79.1-41.7 µg L^{-1} from LFHs to UFHs. The zinc content in drinking water varied from 12.0-217 µg L^{-1}. The results are almost same as reported by Jeelani (2010). The data showed a very significant variation across altitudinal zones ($F_{2, 12}$ =958.62, p=0.0001) at significance level of 0.05.

The socio-economic character of the people in the foot hills was found having strong impact on the human health. The households/people in the sample villages in the study area have two-third percent (63.89%) dependence on locally cultivated essential trace element deficient foods and only about 36.11% food including both vegetarian and non-vegetarian is bought from the market. The dependence of people on local food items increases from LFHs to UFHs from 56.54% to 71.25% respectively and dependence on market foods decreases from 43.46% to 28.75% from LFHs to UFHs respectively. The data showed a very significant variation across altitudinal zones ($F_{2, 6}$ =185.6, p=0.0001) at significance level of 0.05.

About 69.64% of the households employed inappropriate methods of cooking foods and that too in an inappropriate way. They resort to deep and long period braising, blanching, frying and boiling methods of cooking that cause nutrient loss or make them non-bioavailable. There was found a little variation in the percentage of households employing these cooking methods from LFHs to UFHs. It varies from 69.69% to 68.42% from LFHs to UFHs respectively. These cooking methods were mostly employed in LFHs-1 than other zones and sub-zones of foot hills settlements. In LFHs-1, about 75.84% households employed these methods. The data showed a very significant variation across altitudinal zones ($F_{2, 6}$ =185.6, p=0.0001) at significance level of 0.05.

Most of the people in the foot hill settlements were using iodized salt in cooking foods and making tea. About 77.92% of the households used iodized salt and 22.08% households relied on rock salt in the study area. The use of iodized salt showed a decrease with altitude from LFHs to UFHs from 80.08% to 26.32% respectively. The data of households using iodized salt showed a very significant variation across altitudinal zones ($F_{2, 6}$ =394.47, p=0.0001) at significance level of 0.05. About half of the population was drinking boiled water in the area. About 42.46% of the households used boiled water for drinking. The use of boiled drinking water decreased dramatically with altitude from LFHs to UFHs from 44.25% to 0.0% respectively. The data about use of boiled drinking showed a very significant variation across altitudinal zones ($F_{2, 6}$ =2.92, p=0.0001) at significance level of 0.05.

About 15.71%, 36.52% and 47.77% households in the study area were having low (Rs. <5, 000 $month^{-1}$), medium (Rs. 5, 000-10, 000 $month^{-1}$) and high (Rs. >10, 000 $month^{-1}$) income status respectively. The percentage of people in low, medium and high income groups showed a change with altitude from LFHs to UFHs from 15.26%, 36.51% and 48.23% to 26.3%, 36.8% and 36.9% respectively. The data about low income group showed a very significant variation across altitudinal zones ($F_{2, 6}$ =63.44, p=0.0001) at significance level of 0.05.

The study also revealed that there is made no use of essential trace element such as copper and zinc rich fertilizers. The fertilizers such as zinc sulphate and copper sulphate are not used.

Human health is determined and conditioned to a great extent by the physico-chemical (essential trace elements) and socio-economic factors. Whenever there is deficiency or toxicity of these elements in the human body, there occurs a series of health ailments. It was found that out of population surveyed; about 11.98% people suffered from different essential trace element deficiency diseases. The percentage of people suffering from some trace element deficiency related ailments increased from 11.89% to 14.13% from LFHs to UFHs. But, within the LFHs, there was revealed a decline in the suffered people from 12.27% to 11.66% from LFHs-1 to LFHs-2.

About 8.34% were found suffering from thyroid disorders in the area. At macro-altitudinal zone level, there was found increase in the percentage prevalence of thyroid cases from LFHs to UFHs from 8.14% to 13.04% respectively. The highest (17.46%) and lowest (0.00%) percentage of people suffering from thyroid ailments in the area were found in SS22-ANG in UFHs and SS10-BAR in LFHs (LFHs-1) respectively. About 1.98% persons surveyed were found suffering from bone and nerve ailments. About 1.67% people were found to be suffering from diabetes (i.e., diabetes mellitus-II). The percentage prevalence of diabetes in the foot hills decreased from LFHs to UFHs from 1.69% to 1.09% respectively.

It was also found that about eight sample villages out of twenty three fell in very high (Chachmolla, Narwaw, Bindoo Zalan Gam and Kundribal) and high (Bidder Hayat Pora, Awind Gund, Hala Pora and Raing Mandoo) essential trace element disease risk zones after computing composite score. In very low disease risk zone, only three sample villages namely Kata Pora, Sedheve and Marg Bal fell.

6.2. SUGGESTIONS

The important, appropriate and integrative suggestions for improving the essential trace element content in the diet of the people in the area and minimizing the magnitude of people suffering from different essential trace element deficiency diseases are given as:

- To enrich the soils of the foot hills, it seems pertinent to treat the soils systematically after prioritizing them on the basis of deficiency. So, copper and zinc as absorbable compounds such as fertilizers fortified with macro-element fertilizers should be used in all the risk zones especially the very high (Chachmolla, Narwaw, Bindoo Zalan Gam and Kundribal) and high (Bidder Hayat Pora, Awind Gund, Hala Pora and Raing Mandoo) disease risk zones.
- Dietary diversification is a sustainable long-term approach to improve the intake of several micro-nutrients simultaneously. This process should be employed at the community or household level to increase the intake of bioavailable zinc, copper and iodine in all the risk areas especially the high (Bidder Hayat Pora, Awind Gund, Hala Pora and Raing Mandoo) and very high (Chachmolla, Narwaw, Bindoo Zalan Gam and Kundribal) risk zones to improve the nutrient content especially copper of the foods.
- Where micronutrient deficiency is widely distributed in a population and dietary modification or diversification is difficult to achieve, fortification of centrally processed and widely used foods (staples) is an appropriate alternative. The staple food i.e., rice can be used for fortification of essential trace elements such as copper and zinc to combat their deficiency in the humans. Therefore, government should take a systematic and immediate step in fortifying and supplying the essential trace element rich fortified rice to all the risk zones with special focus on high risk area, so, that people who are more dependent on the market food items easily get essential trace element rich diet.
- Bio-fortification is a latest technique for dealing with trace element deficiencies in the developing countries. It focuses on intrinsic enrichment of micronutrients in plant parts that are used for food while the plants are still

growing. So, it is a very applicable technique when it comes to providing nutrients for the rural poor population, who rarely have access to commercially fortified foods. Agronomic bio-fortification for enrichment of cereal grains and vegetables with nutrients like copper and zinc should be given special focus in the risk areas.

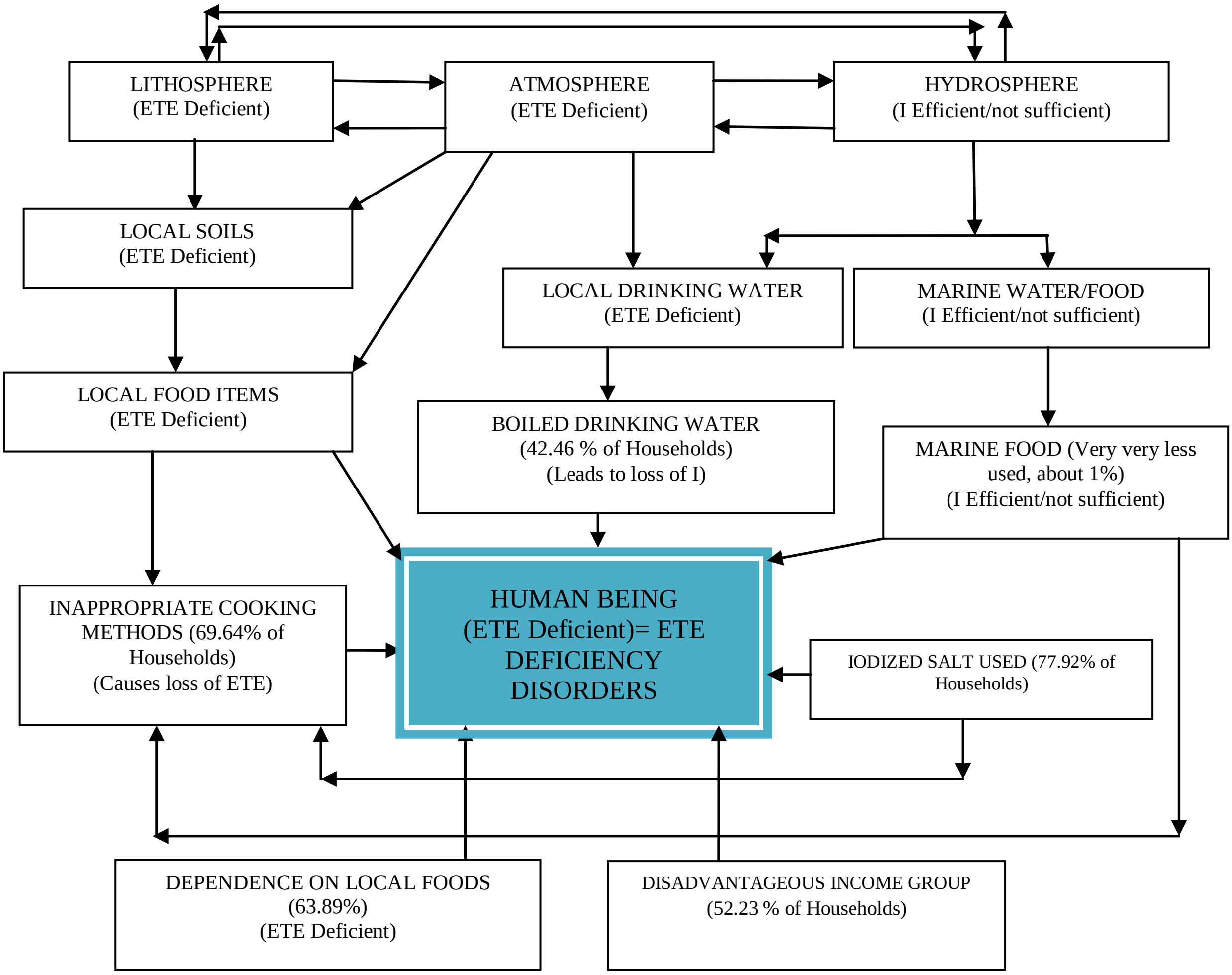
- Plant foods (vegetarian food items) are the major staples of diets in developing countries, as well as in the study area. But, plant-based diets are often associated with micronutrient deficits, coupled by poor micronutrient bioavailability caused by certain factors. So, household strategies like germination, microbial fermentation or soaking, malting and the like that reduce the content or counteract the inhibiting effects of some factors on micronutrient bioavailability are urgently needed in the whole study area especially in the high and very high disease risk zones.
- The appropriate methods of cooking should be followed in the whole area with main focus in very high and high risk zones. If sometimes other methods are required, they should be followed at medium temperatures and without discarding boiled water.
- All the risk zones should be supplied with salt fortified with required quantity of iodine with main focus in very high and high risk zones in which the UFH sample villages with least use of iodized salt fell. The concerned government departments should take astern action against the people making, supplying and selling non-iodized salt.
- Public awareness programmes at community level should be conducted to disseminate the information related to the importance of balanced nutrition. Nutrition education should be made a part of school curriculum with a special focus on the deficiency of nutrients and their consequences on human health.

6.3. PLANNING STRATEGY

In the area under study, the soils under cultivation are deficient in essential trace elements. The concentration of these elements is also low in drinking water. It was found that the people had about two-third dependence on locally cultivated foods. The prevalence of inappropriate cooking methods was also revealed. About 69.69% of the households employed inappropriate methods of cooking. The people made no use of essential trace element rich fertilizers. About 77.92% and 42.46% households used iodized salt and boiled water respectively. In the result, about 11.98% people suffered from different essential trace element deficiency diseases.

The schematic diagram (Fig. 6.1) highlights the efficiency of natural systems in terms of the concentration and availability of essential trace elements and their transfer and loss from natural systems to human beings at different stages in the foot hill settlements of Pir Panjal range in Kashmir valley. All the natural pools of mountainous environments are deficient in essential trace elements because of unfavorable slope, unfriendly agricultural activities, and the like. And the problem is coupled when the socio-economic factors also work in the negative direction. The diagram highlights the general status of essential trace elements in the biogeochemical phases of natural environment in general with special focus in relation to the study area. It points out the transfer and loss of essential trace elements at different stages of trace element transfer under the influence of both natural and anthropogenic processes working in the area till it reaches the human body. In nutshell, it could be deduced as the human beings of the area are at risk of essential trace element deficiency diseases because of the inadequate intake of these nutrients that is in turn due to the low essential trace element contents in the soils and drinking waters of the area coupled by inappropriate socio-economic factors like bad cooking methods, greater dependence of local nutrient deficit foods and greater use of vegetarian diet.

Transfer and Loss of Essential Trace Elements (ETEs) in the Study Area



Source: Modified after Kabata Pendias and Mukherjee, 2007

Fig. 6.1

Planning Measures for Abatement of Essential Trace Element Deficiencies and Maintenance of Good Health

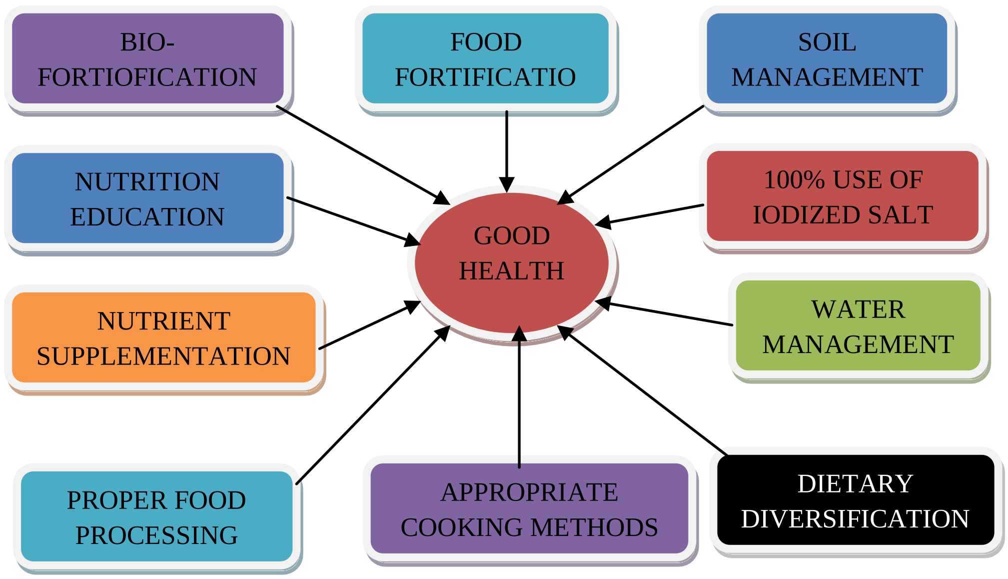


Fig. 6.2

To combat all the aforementioned problems to improve the health of the people and particularly minimize the magnitude of essential trace element deficiency diseases, certain measures are suggested as below:

6.3.1. Soil and Water Management

Soil and water treatment is a sustainable and long term way to improve the intake of some essential trace elements by human beings. The nutrients like zinc, iodine, and copper can be simply added to nutrient deficient drinking and irrigational water through fertigation to increase the intake of these nutrients by plants, animals and human beings simultaneously. The drinking water must be properly chlorinated and made coliform free in reservoirs so that people take it without boiling to save iodine.

So far the deficiency of the essential trace elements in the study area is concerned, these elements in bioavailable forms and required concentration should be added to the drinking and irrigational waters in all the risk zones.

The treatment of soil is a heavy but very important step in the management of trace element related disorders in the plants, animals and human beings. Soils deficient in micronutrients can be enriched by adding micronutrient rich fertilizers to soils in a proper proportionate. The essential trace elements like zinc and copper can be added to soils in the form of highly absorbable fertilizers such as zinc sulphates and copper sulphates respectively. Since, iodine is not an essential mineral required by plants, it is not necessary to add it to the soil. The best way for the fertilization of soil with these nutrients is to fortify them with the macronutrient fertilizers like NPK. The macro-mineral fertilizers should be used in a proper proportion for they otherwise may disturb the soil trace element chemistry. The excessive nitrogen fertilization i.e., common in the study area as well, reduces the availability of copper and other trace elements in the soil (Ryan, 2009).

Largely, to enrich the soils of the foot hills, it seems pertinent to treat the soils systematically after prioritizing them on the basis of deficiency. So, copper and zinc as absorbable compounds such as fertilizers fortified with macro-element fertilizers should be used in all the risk zones especially the very high and high risk areas.

The proper management of land use/land covers to maintain the soil texture, soil organic structure and pH is important for the management of trace element deficiency disorders. The deforestation in uplands and horticulturalization in plains are negative steps that need to be avoided. The change in land use/land covers changes the soil texture, organic matter and pH that are closely related with the behavior of trace elements in the soil.

6.3.2. Dietary Diversification

Dietary diversification is a sustainable long-term approach to improve the intake of several micro-nutrients simultaneously. This process employed at the community or household level has a potential to increase the intake of bioavailable zinc, copper and iodine. It is a well established fact that the non-vegetarian foods are rich in essential trace elements except copper. However, it should not be taken as a yardstick, copper is available in plant foods only when the soil is rich in bioavailable copper. Two important strategies have been included in it. These are agricultural interventions and production and promotion of non-vegetarian foods through animal husbandry or aquaculture. Generally, agricultural interventions focused on plant-foods may have little impact on intake of bioavailable nutrients such as zinc (Roohani, *et al*., 2013) and iodine. But, in terms of copper, plant based foods are essential and rich sources of copper provided the rich varieties are grown and eaten. But, from the vegetarian diet, some promising benefits may be realized if accompanied by favorable processing strategies to reduce the levels of substances that inhibit the zinc and iodine absorption, such as phytate. The zinc and iodine rich foods could be made available through local animal husbandry and aquaculture. Red meat, milk and cheese are rich sources of zinc than poultry, eggs and sea foods. The richest sources of iodine are sea foods such as fish. Care must be taken to avoid potential adverse effects of the above strategies, such as aflatoxin contamination of germinated cereals, loss of water-soluble nutrients from soaking cereal flours, and displacement of breast milk by increased intakes of other foods (Gibson and Anderson, 2009).

In the area under study, the iodine and zinc deficiency could be combat through local animal husbandry and aquaculture. Moreover, special attention should be given towards use of essential trace element rich foods such as meat, milk, dry foods, fish, and the like. Also, the cultivation of varieties of crops rich in copper may produce promising results.

6.3.3. Nutrient Supplementation

Nutrient supplementation programs are useful for targeting vulnerable populations, which are at particular high-risk of micronutrient deficiencies. The easiest way to supplement zinc, copper and iodine could be to include it in programs such as Anganwadis (ICDS) already delivering daily or weekly or monthly nutrient supplements for the prevention of iron and folic acid deficiency and other nutrient deficiencies. When formulating multi-nutrient supplements, it is recommended that salts providing readily absorbable zinc, like $ZnSO_4$, zinc gluconate or zinc acetate are used because they are absorbed more efficiently (Brown, *et al*., 2004).

This method is a crucial one in terms of that it needs proper medical care and should be followed only under medical supervision.

6.3.4. Food Fortification

Food fortification is a very cost-effective and sustainable approach to overcome micronutrient deficiency than supplementation. Where micronutrient deficiency is widely distributed in a population and dietary modification or diversification is difficult to achieve, fortification of centrally processed and widely used foods (staples) is an appropriate alternative. Multiple trace elements could be added to the foods to overcome the problem of their deficiency. For such multiple interventions synergistic and antagonistic interactions between micronutrients have to be taken into account during the development of appropriate formulations (FAO/WHO, 2004). In general, the food selected for fortification should be one that is widely consumed in stable and predictable amounts by a certain population. Zinc and copper can be added to several foods including milk, cereals, flours, fruit juices, sugar and water (Rosado, 2003). Among the various criteria, the following conditions should be fulfilled while choosing a vehicle for such purposes: i) food chosen as a vehicle should be ingested by the target population in sufficient quantities, ii) the fortified food should be stable and physico-chemical properties such as appearance, texture and flavor should not change when the nutrient is added, iii) the added nutrient should be bioavailable, iv) fortification of the food should not significantly increase its price and v) fortification should be carried with available technology and at low cost.

Among several zinc compounds that are available for fortification, zinc oxide and $ZnSO_4$ are least expensive. $ZnSO_4$ theoretically provides more absorbable zinc because of its greater solubility (Wolfe *et al*., 1994). The two main compounds of copper that are best for food fortification are copper gluconate and copper sulfate and the latter is highly reactive and hygroscopic, and less costly than the former (Rosado, 2003). Fortification can also be targeted specifically to increase the intake of micronutrients in certain groups of population by identifying the particular food that is mostly used by it. While fortifying multiple minerals, nutrient interactions should be taken into consideration and conservative amounts added. One more important thing is that the amount of fortificant should be considered properly while adding to the food. For this, the present dietary intake, recommended dietary intake and tolerable amounts should be properly taken into consideration.

The technique of food fortification is highly applicable in the area under study. The staple food i.e., rice can be used for fortification of essential trace elements such as copper and zinc to combat their deficiency in the humans. All the risk zones should be supplied trace element rich fortified rice and maize with special focus on high risk area. By following this practice, the section of population that is more reliant on non-local foods would get proper essential trace element rich diet.

6.3.5. Bio-Fortification

Bio-fortification strategies include the application of fertilizers to the soil/foliar sprays and the development of crop genotypes that acquire more nutrients from the soil and accumulate it in the edible parts. So, dietary nutrient intakes can be augmented through a variety of interventions (Stein, 2010). These include both agronomic and genetic bio-fortification of edible crops (Graham, *et al*., 2007; Bouis and Welch, 2010). Agronomic bio-fortification can be achieved by increasing soil nutrient phytoavailability or by applying micronutrient fertilizers. It can be very successful in regions where mineral fertilizers are used to increase crop yields and zinc (or copper) is added to these at the point of manufacture or distribution (Cakmak, 2009). Genetic bio-fortification is predicated on increasing mineral or nutrient acquisition from the soil and its accumulation in edible portions. Most economic analyses suggest that genetic strategies toward zinc bio-fortification are more practical, enduring, and cost effective than dietary diversification, supplementation, or food fortification programs for increasing dietary zinc intakes of vulnerable populations (Stein, 2010; Bouis and Welch, 2010).

Application of micronutrient rich fertilizers to soil and/or foliar seems to be a practical approach to improving grain mineral concentration (e.g., agronomic bio-fortification). Very recently, copper and zinc fertilizer projects at global level have been initiated under Harvest Plus program. These projects aim at evaluating the potential of micronutrient containing fertilizers for increasing their concentration in cereal grains (e.g., rice and wheat) and improving crop production in different target countries (e.g., India, China, Pakistan, Thailand, Turkey, Mozambique, Zimbabwe, and Brazil). Bio-fortification of cereal grains through use of micronutrient containing fertilizers (e.g., agronomic bio-fortification) is required for (i) keeping sufficient amount of available nutrient in soil solution, (ii) maintaining adequate mineral transport to the seeds during reproductive growth stage and (iii) optimizing the success of bio-fortification of staple food crops with mineral through use of breeding tools. Hydrated forms of zinc and copper sulfates are frequently and widely applied and proved fertilizers used as foliar sprays because of their high solubility and low cost.

Harvest plus like programmes of bio-fortification has an appreciable scope in the study area. Agronomic bio-fortification for enrichment of cereal grains and vegetables with nutrients like copper and zinc is a good technique that needs to be followed in the present area in a systematic manner after taking into consideration risk zone prioritization. The high and very high risk zones should be given special preference.

6.3.6. Vegetarian Diet and Food Processing

Plant foods (vegetarian food items) are the major staples of diets in developing countries, as well as in the study area in which the consumption of animal-source foods is often low because of economic concerns. However, such plant-based diets are often associated with micronutrient deficits, coupled by poor micronutrient bioavailability caused by certain factors: interactions between nutrients and other organic components (e.g. phytate, polyphenols, dietary fibre, oxalic acid, protein, fat, ascorbic acid, goitrogens) and pretreatment of food as a result of processing and/or preparation practices. Consequently, household strategies that reduce the content or counteract the inhibiting effects of these factors on micronutrient bioavailability are urgently needed in such settings. Examples of such strategies include: germination, microbial fermentation or soaking to reduce the phytate and polyphenol content of cereals and legumes or vegetarian foods and heating to destroy heat-labile anti-nutritional factors (e.g. goitrogens, thiaminases).

The cationic nutrients such as zinc and copper become partially bioavailable in the gastrointestinal tract due to the inhibitory effects of phytic acids, polyphenols, etc. in the vegetarian food. Phytic acid is the principal dietary factor known to limit zinc bioavailability by strongly binding zinc in the gastrointestinal tract (Hambidge, *et al*., 2011). Re-absorption of endogenously-excreted zinc and copper may also be affected

(Sandstrom, 2001). These foods (such as cabbage, soyabeans, and maize) also contain goitrogens that inhibit the uptake of iodine by the thyroid gland. On the other hand, there are certain chemicals such as proteins, ascorbic, citric, lactic, acetic, butyric acids that enhance the absorption of zinc and copper and other minerals from the plant foods in the human body. Consumption of animal proteins (e.g., meat, eggs and cheese) improves the bioavailability of zinc from plant food items possibly amino acids released from the animal protein keep zinc in solution (Lonnerdal, 2000) or amino acids bind up phytate.

The inhibiting effects of organic compounds in the plant foods can be reduced easily by household food processing and preparation practices such as germination and others. Thermal processing generally enhances the digestibility of the proteins and carbohydrates (if food does not become brown) whereby it increases the absorption of iodine by destroying goitrogens and thiaminases (Gaitan, 1990). Thermal processing and extrusion cooking may cause only modest phytate losses (Hurrell, 2004).

Germination, also termed malting, induces hydrolysis of phytate and hence increases bioavailability of zinc, iron and other nutrients. The phosphates in phytate reduce bioavailability of divalent and trivalent cations (Zn, Cu, Fe and Mg) at physiological conditions of the small intestine (Hurrel, 2004).

Milling and household pounding is another technique of phytate reduction. It is used to remove the bran and/or germ from cereals such as rice, wheat, and maize. Phytate is removed by this process if it is localized in the outer aleurone layer (rice and wheat). Milling, a non-enzymatic method, has been successful in reducing phytic acid content in plant-based staples (Schlemmer, *et al*., 2009). So, it enhances the bioavailability of nutrients from the plant foods, but it also reduces the mineral content simultaneously. Proper care needs to be taken while milling the cereals.

Microbial fermentation hydrolyses the complex phytic acids to simpler ones through the action of microbial phytase enzymes (Sandberg, 1991). It reduces up to 90% phytate content in the plant foods. Fermentation also produces some organic acids that enhance the micronutrient absorption. It also improves the protein quality that in turn increases the bioavailability of nutrients in the small intestines.

Therefore, the above mentioned techniques of food processing and preparation should be given a due importance. These techniques should be followed in practical in all the risk zones with special focus on the high (Bidder Hayat Pora, Awind Gund, Hala Pora and Raing Mandoo) and very high (Chachmolla, Narwaw, Bindoo Zalan Gam and Kundribal) risk zones.

6.3.7. Appropriate Cooking Methods

Cooking is an important process for adding taste to the foods and improving their digestibility. But, some cooking methods instead of enhancing the nutrient bioavailability cause loss of nutrients during cooking. In 1990, it was found at Vanderbilt University that cooked foods contained about 60 to 70 percent of the mineral calcium, copper, iron, magnesium, zinc and other minerals found in uncooked foods. Boiling, soaking, parching, frying and stewing of vegetables caused most of the loss of minerals in them. Actually, it occurred when excessive cooking was done and water was discarded.

Iodine content of food is lowered by 37 to 70 percent in Indian methods of cooking processes. Frying reduces the iodine content by 20 per cent, grilling by 23 per cent and boiling by as much as 58 per cent. The loss of iodine in cereals is 30–60 per cent during boiling; frying of vegetables results in loss of 25–52 per cent; steaming results in loss of 30 per cent; in fish 20 per cent is lost by frying or grilling and as much as 58 per cent by boiling (Srilakshmi, 2012).

If the above mentioned methods of cooking are employed with less heating and without discarding the used water, there will be very least loss of nutrients. There are some methods in which most of the nutrients are retained in the food. Pressure cooking and stir-frying retained a high percentage of nutrients as compared to other cooking methods. One of the simplest ways to reduce mineral loss is through using less water to cook vegetables. Much nutrient loss occurs when vegetables are cooked in large amounts of water; the nutrients leach into the water which is then discarded. Cut vegetables or fruits into large, rather than small, pieces before cooking, as a greater surface area helps nutrients break down for consumption more easily. Don’t overcook food; the less cooking time is the best. Finally, cover the cooking container tightly to keep steam and nutrients from escaping.

Since, most of the households in the very high and high risk zones follow inappropriate cooking methods, the above mentioned appropriate methods of food cooking should be followed with special focus in them. Bad cooking contributes badly in all the zones. The good methods of cooking like pressure cooking and stir-frying should be followed in the whole area with main focus in very high and high risk zones.

6.3.8. Full Coverage under Universal Salt Iodization Programme

In India, the universal salt iodization programme was started somewhere around 1990. Despite the impressive progress in provision of iodized salt and coverage of households but much remains to be done in terms of quality. The household coverage of adequately iodized salt has undergone many ups and downs. In 2009, nearly 20% of households were found to be consuming inadequately (i.e., iodine content <15 mg kg^{-1}) iodized salt and 9% using salt that was not iodized (UNICEF, 2011). A significant barrier towards improving the distribution of affordable, adequately iodized salt is the lack of capacity and/or commitment of the medium and small producers and traders (Vir, 2008). Adequate access and availability of appropriately iodized salt, particularly for the vulnerable populations should be ensured. Monitoring should be strengthened at all the levels. Iodine levels in salt used at the household level should be checked on a regular basis through school children or ICDS centers. The quality of salt received at PDS outlets should be checked. A well defined and compelling strategy is required in order to reach the last 30% of households that are likely to be least accessible and most socio-economically disadvantaged (Rah, *et al*., 2013).

Salt iodization is a very important way of food fortification that needs to be universalized in the area under study. All the risk zones should be supplied with salt fortified with required quantity of iodine particularly the high (Bidder Hayat Pora, Awind Gund, Hala Pora and Raing Mandoo) and very high (Chachmolla, Narwaw, Bindoo Zalan Gam and Kundribal) risk zones in which fall the UFH sample villages with least use of iodized salt.

6.3.9. Nutrition Education

Nutrition education is the primary and main step involved in reducing the magnitude of essential trace element deficiency diseases. Public awareness programmes at community level should be conducted to disseminate the information related to the importance of balanced nutrition. Nutrition education should be made a part of school curriculum with a special focus on the deficiency of nutrients and their consequences on human health. And whatever strategies are possible should be employed to reduce the magnitude of disease burden on humanity.

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ANNEXURES

Department of Geography and Regional Development, University of Kashmir, Srinagar-190006
Household Survey-(Ph.D Research Work)

Research Title: Trace Elements and Human Health in the Foot Hill Settlements of Pir Panjal Range in Kashmir

Name of the village…………………Name of household head………………………

Age…..…Education…..…Occupation………..Household strength……..................

.No. of Males……….. No. of Females……….. No. of Children…………….....

Income/month…………………

➢ Socio-Economic information of the household

S.NO.	Relationship with Head	Sex (M/F)	Age	Marital Status	Education	Occupation	Weight of the body (kg)
1							
2							
3							
4							
5							
6							
7							

➢ Occupation of the Head of Household

a Primary activity b. Secondary Activity c. Service (clerk, etc.)

- Family Structure a. Nuclear 1 Joint 2

  b. Total number of persons living in the family ………..(If Joint)

- Economic Base

  Family monthly income from all sources Rs……………………

  Expenditure on food/month: Rs……………………………

  Expenditure on health/month: Rs……………………………

➢ Land in Possession

a. Total land in (kanals) ……….. Cultivated …........ Uncultivate…………..

b. Irrigated ………………………….. Unirrigated………………………………

- **Cropping pattern**

Season	Crops grown	Land under each crop	Production/Kanal=Yield
Summer			
Winter			

- **Livestock:**

Kind of Livestock	Number	Kind of livestock	Number
Cows		Goats	
Horse/ponies		Chickens	
Bullocks		Others(Specify)	
Sheep			

- **Foods used for eating**

Type of food	Dependence on local foods (household level)	
	Required or Used (in kg/month)	Bought from market (kg/month)
Cereals **Rice** **Wheat** **Maize**		
Pulses		
Fish		
Fruits		
Vegetables		
Roots/tubers		
Meat		
Chicken		
Eggs		
Milk		

- **Trace element related diseases prevalent (On the basis of prescriptions)**

Name of the disease	Number of Cases
ZINC (deficiency) Diabetes	
COPPER (deficiency) Bone and nerve problems	
IODINE (deficiency) Hypothyroidism	
Others	

➢ Quantity of fertilizers used

Type of fertilizer	Quantity (kg/kanal/year)
Diammonium Phosphate	
Urea	
Urea ammonium phosphate	
Potassium sulfate	
Others	

➢ Drinking water source

Spring		Stream		Tap (Spring)		Tap (Stream)	
Tube well							

➢ Type of utensils used for cooking

Copper		Baked clay	
Steel		Aluminium	
Iron			

➢ Cooking Method

Deep Frying		Light Frying	
Frying (mostly)		Not Frying (Salad type)	
Deep Blanching		Light Blanching	
Deep Braising		Light Braising	
Pressure Cooking		Boiling	
Long Period Heating			

Remarks:

……………………………………………………………………………………………

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……………………………………………………………………………………………

Signature of the
Research Scholar

Note: The schedule is only for educational purposes.

PLATE-1: **PLATE-2**

PLATE-3 **PLATE-4**

The plates 1, 2, 3 and 4 show soil sampling methodology of soils under forest land use

PLATE-5 **PLATE-6**

PLATE-7 **PLATE-8**

The plates 5, 6, 7 and 8 show soil sampling methodology of soils under horticultural land use

PLATE-9

PLATE-10

PLATE-11

PLATE-12

The plates 9, 10, 11 and 12 show soil sampling methodology of soils under agricultural land use

PLATE-13

PLATE-14

PLATE-15

PLATE-16

The plates 13, 14, 15 and 16 show water sampling methodology of stream water

PLATE-17 **PLATE-18**

PLATE-19 **PLATE-20**

The plates 17, 18, 19 and 20 show water sampling methodology of tap water fed by spring/stream

PLATE-21 **PLATE-22**

PLATE-23 **PLATE-24**

The plates 21, 22, 23 and 24 show water sampling methodology of spring water

PLATE-25 **PLATE-26**

PLATE-27 **PLATE-28**

The plates from 25 to 28 show socio-economic and health survey of the sample villages

PLATE-29 **PLATE-30**

PLATE-31 **PLATE-32**

The plates from 29 to 32 show socio-economic and health survey of the sample villages

PLATE-33 **PLATE-34**

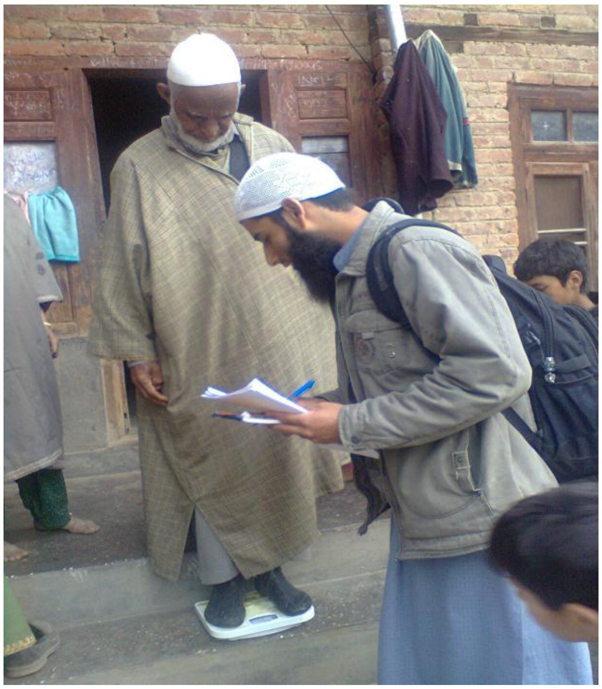

PLATE-35 **PLATE-36**

The plates from 25 to 36 show socio-economic and health survey of the sample villages

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RESEARCH ARTICLE

GEO-ECOLOGY OF ZINC-COPPER DEFICIENCY DISEASES IN THE FOOT HILL SETTLEMENTS OF PIR PANJAL RANGE

*Rafiq Ahmad Hajam, Ghulam Mohmad Rather and Tasawoor Ahmad Kanth

Department of Geography and Regional Development, University of Kashmir, Srinagar, India -190006

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ABSTRACT

The present research work was an attempt to investigate the geo-ecology of Zinc (Zn) and Copper (Cu) deficiency diseases in the foot hill settlements of Pir Panjal range in Anantnag district of Kashmir valley. The study revealed that the diet of the people in the area is determined by their financial status which forces them to rely mostly on locally cultivated food items. More than 62.4% households comprising low (Rs. <5, 000 / month) and medium (Rs. 5, 000-10, 000 / month) income status households have inadequate income to afford proper food, health and other services. It was found that the Zn and Cu content in all the soil samples (Zn: 0.570-1.972 mg kg^{-1}; Cu: 0.930-3.968 mg kg^{-1}) are less than the average values in the world soils (Zn: 64 mg kg^{-1}; Cu: 20 mg kg^{-1}). The Zn and Cu content in drinking water sources (Zn: 0.016-0.217 mg L^{-1}; Cu: 0.012-0.018 mg L^{-1}) were found more than the average concentrations of Zn and Cu in world fresh water sources (Zn: 0.0006 mg L^{-1}; Cu: 0.002 mg L^{-1}) but less than required and acceptable limits (BIS: Zn: 5 mg L^{-1}; Cu: 0.05 mg L^{-1}). Study revealed that about 3.1 percent and 2.3 percent of the population in sample villages suffered from zinc and copper deficiency diseases respectively. These deficiency diseases can be attributed mainly to the deficiency of the Zn and Cu in soils and drinking waters (and hence food), high dependence on local foods (67.89%) and inappropriate cooking methods and lifestyle.

INTRODUCTION

The zinc and copper are recognized as the essential trace elements for human health. They are present in the earth's crust in concentrations less than 0.1% (<1000 mg kg^{-1}) or ordinarily present in plant or animal including human beings tissues in concentrations less than 0.01% (<100 mg kg^{-1}) of the organism's dry weight (Adriano, 2001). Though required in small amounts or traces, they act as components of hemoglobin, DNA, RNA, and various enzymes (Warren, 1991). WHO/BIS has recommended a standard requirement of each trace element for human health. All essential trace elements either in excess states or in deficit states are known to create serious health problems particularly in the areas where these are regionally deficit or surplus (Hunter and Akhtar, 1991). The concentration of trace elements in soil, water or food items is mainly determined by the geological conditions of the area (Keller, 1999; Learmonth, 1988; Jeelani, 2004, 2010; Pyle, 1979). Regional differences in essential minerals in the soil, water or air and hence human diet occur both in developed and developing countries, but their effects are usually more evident in the latter, largely because of imbalance and mismanaged nutrition and reliance on local food products (Oliver, 1997) cultivated in mineral deficit soils.

Corresponding author: Rafiq Ahmad Hajam,
Department of Geography and Regional Development, University of Kashmir, Srinagar, India -190006.

Food derived from the plants (and animals) grown in soil and water is the main source of zinc and copper for humans. They also derive these elements from atmosphere. But the diets of people are either deficit or are rendered deficit of these minerals through inappropriate cooking and other lifestyles. Good dietary sources of zinc are meat and fish. The recommended dietary intake of zinc for humans varies from 7-15 mg $person^{-1}$ d^{-1}. Generally, requirement of copper for humans ranges from 1.5-4 mg $person^{-1}$ d^{-1}. However, dietary habits including agricultural and food processing practices greatly influence the values of these minerals.

Both zinc and copper are essential components of several proteins and metalloenzymes. About zinc it has been said that it behaves like a traffic policeman, directing and controlling the flow of processes in the organism and regulating enzyme systems and cells (Komatina, 2004). Copper is a primary factor in the oxidation-reduction reactions and hemoglobin formation. Though severe zinc deficiency is not widely prevalent, mild to moderate zinc deficit is ubiquitous in nature. Zinc deficiency retards the immune function, causes diabetes, alopecia, skin lesions, impaired taste and smell, delays sexual and bone maturation, diarrhea, and many other disorders. The infants and children are most vulnerable to zinc deficiency. The older adults, non-healthy adults, and some vegetarians are also at risk of zinc deficiency.

The deficiency of copper in humans may result in many diseases such as: retarded growth, hair and weight loss, disorders of nervous system, osteoporosis and Menke's syndrome. While as, an excess of copper causes Wilson's disease, mostly ending in death (Aaseth, and Norseth, 1986). A number of experimental studies have been conducted to find out the content of zinc and copper present in the soils and waters in the world and many clinical studies to trace out the diseases related to their deficiency and toxicity in the human body. The present study is an attempt to investigate the geo-ecology of zinc and copper deficiency diseases in human beings by analyzing the concentration of zinc and copper minerals in the soils and drinking waters and influence of cooking methods and dietary sources.

The study area is a part of the Kashmir region located roughly between the elevations of 1,800 meters to 3,000 meters above the mean sea level (m AMSL). The area lies between 33^0 23′ 08" N to 33^0 65′ 90" N latitudes and 74^0 55 75^0 10' 05'' to 75^0 35′ 20'' E longitudes, covering an area of about 547.04 km^2 (Figure 1) with a population of about 1, 88,055 (Census, 2011). The soils of the concerned area vary in origin from alluvial to lacustrine and glacial (Figure 2 and Table 1).

METHODS AND MATERIALS

A comprehensive methodology divided into many steps based on the materials and techniques used has been adopted to carry out the present work. A schematic diagram of the various methodological steps is provided in the figure 3 and described under the following headings.

GIS techniques

The study area was delineated from the SOI toposheets of 1:50,000 scale of 1971 with numbers as 43 O/2, 43 O/3, 43 O/6 and 43 O/7 with the help of Arc View 3.2a software. The base contour was taken as $1,800^{th}$ m AMSL and top one as $3,000^{th}$ m AMSL (Raza *et al.,* 1978). These two contours were connected on the lateral sides by taking the watershed limits through digitization. By digitizing $2,400^{th}$ m contour, the area under study was divided into two altitudinal zones, namely, Lower Foot Hills (LFHs) and Upper Foot Hills (UFHs) varying in altitude from $1,800^{th}$-$2,400^{th}$ m and $2,400^{th}$-$3,000^{th}$ m respectively. The LFHs are characterized by good permanent human occupancy while as the UFHs experience mostly seasonal human inhabitations.

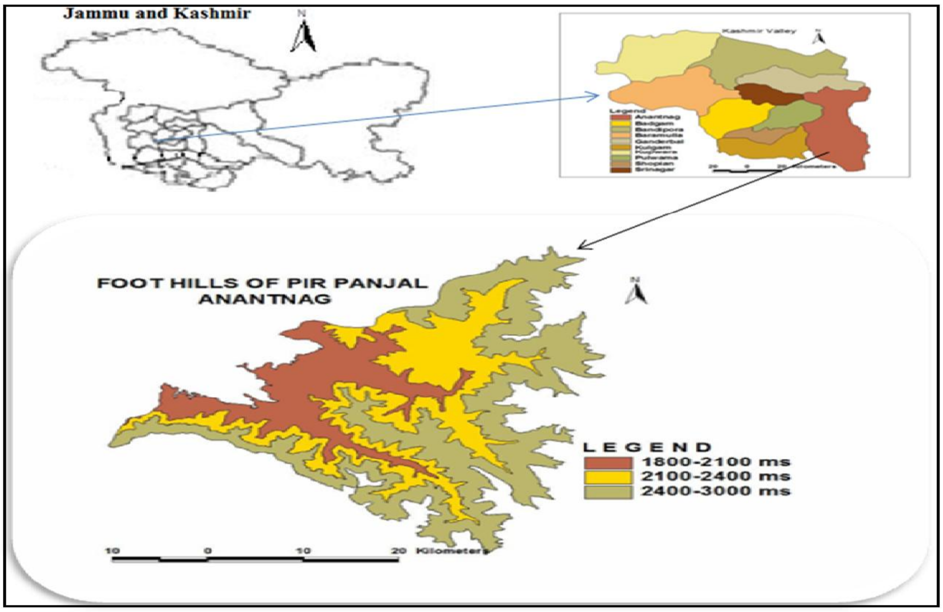

Figure 1. Location map of Foot Hills of Pir Panjal range in Anantnag (Generated from SOI toposheets, 1971)

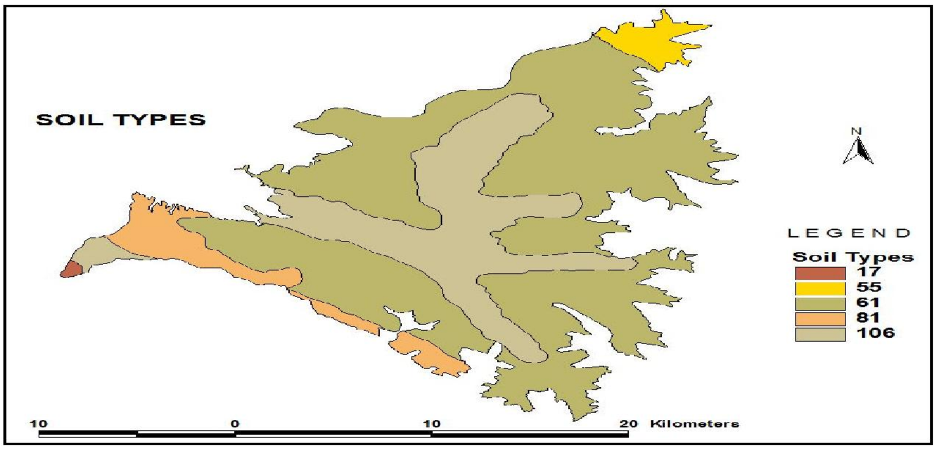

Figure 2. Soil map of the study area (Generated from Soil Map of J & K, ICAR, Nagpur-2010)

Table 1. Soil types with codes and description

Code	Description	Soil Type
17	Dominantly rock outcrops; associated with shallow, loamy, calcareous soils on steep to very steep slopes with loamy surface, strong stoniness and severe erosion	Lithic Cryorthents
55	Deep, well drained coarse-loamy soils on gentle slopes with loamy surface, moderate erosion and slight gravelliness; associated with deep, well drained, coarse loamy, calcareous soils with loamy surface, moderate erosion and slight gravelliness.	Typic Cryofluvents
61	Medium deep, well drained, loamy-skeletal soils on moderate slopes with loamy surface, severe erosion and strong stoniness; associated with medium deep, well drained, fine-loamy soils with loamy surface, moderate erosion and moderate stonniness.	Typic Udorthents/ Dystric Eutrochrepts
81	Deep, moderately well drained, fine soils on very gentle slopes with loamy surface; associated with deep, well drained, fine-loamy soils with loamy surface.	Typic Hapludalfs/ Dystric Eutrochrepts
106	Medium deep, well drained, fine loamy soils on moderate slopes with loamy surface and moderate erosion; associated with shallow, excessively drained, loamy soils with loamy surface, moderate erosion and strong stonniness.	Dystric Eutrochrepts/ Lithic Udorthents

Source: Modified from Soil Map of J & K, ICAR, Nagpur-2010

For comparative analysis, by digitizing 2,100th m contour, the LFHs were further sub-divided into two sub-zones namely, LFHs-1 and LFHs-2 varying in elevation from 1,800th-2,100th m and 2,100th-2,400th m (Figure 4a). Stratified random sampling technique was used for the selection of sample sites (sample villages, and soil and water sample sites) and sample households as shown in Table 2 and 3 and Figures 4b, 5a and 5b.

Field Work

The soil samples were collected in clean unused polythene bags and were labeled properly. A clean spade was used to take the soil samples. In order to reduce variability, a composite sample was obtained from each sample site. A composite sample comprised of five sub-samples taken from each sample site in 10 m × 10 m grid format.

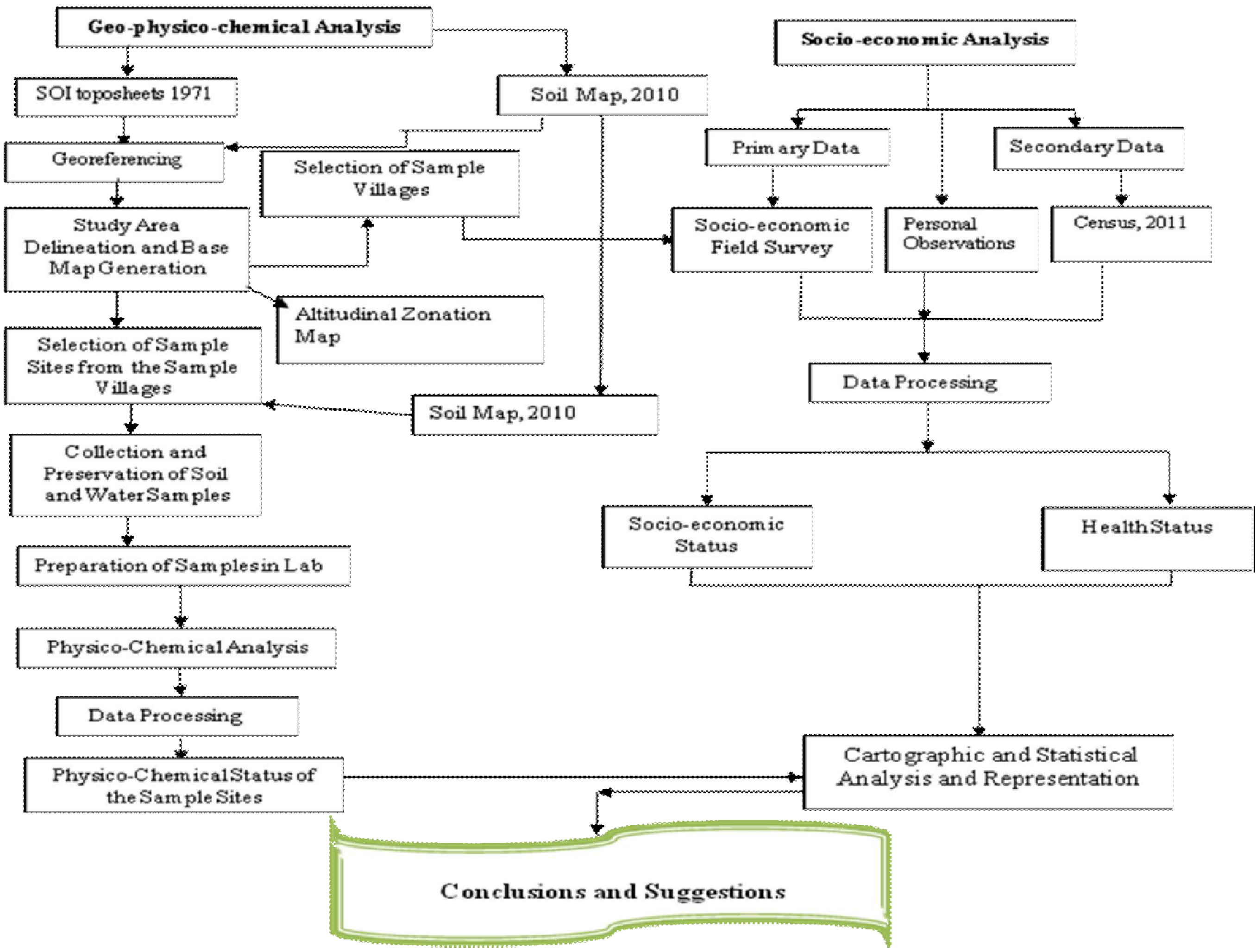

Figure 3. Flow Chart of Methodology

Four sub-samples were taken from four corners of the square and one from the center. Soil samples were taken from depths of 0-20, 0-40 and 0-60 cm in relation to different major land uses i.e., agricultural, horticultural and forest respectively (Brady, 1991; Pennock *et al*., 2008). Water samples were collected in clean unused plastic bottles from the selected sample sites and were labeled properly and reached to the lab within 24 hours. Both types of samples were analyzed in Research Centre for Residue and Quality Analysis Lab, SKUAST, Shalimar. The socio-economic survey was done through the structured schedules to give the socio-economic picture of the area and to assess the dependence of people on local food items, income status, methods of cooking, and percentage of households purchasing food from the market. The data regarding the prevalence of zinc and copper deficiency diseases was collected through primary survey. The hospital records and concerned medical consultants were also consulted.

Lab Work

The soil samples were air-dried, crushed with a wooden roller, passed through a 10 mesh (<2 mm) sieve, and then ground in an agate mortar. The recovered <63 µm particles were separated for chemical analysis. The samples were analyzed under Atomic Absorption Spectrophotometer (AAS-4141, Electronic Corporation Limited, India). The total concentration of Zn and Cu was determined after 4-acid digestion (HF, $HClO_4$, HNO_3 and HCl) by AAS. The soil samples were analyzed for Zn, Cu, pH and OM. While as water samples were analyzed for Zn, Cu and pH.

Table 2. Sample Frame

Macro Regions (Altitudinal Zones in meters AMSL)	Micro Regions (Sub-altitudinal Zones in meters AMSL)	Sample Villages	Total No. of Households in the Sample Villages	Number of Households Surveyed	Percentage of Surveyed Households to total Number of Households	Soil Type (Codes)	Number of Samples Taken	Main Water Source	No. of Samples Taken
Lower Foot Hills (LFHs)-1,800-2,400	LFHs-1 (1,800-2,100)	Bidder Hayat Pora	77	08	>10	61	01	Tap fed by a Spring	01
		Bindoo Zalan Gam	519	52	>10	106	01	Tap fed by a Stream	01
	LFHs-2 (2,100-2,400)	Hala Pora	292	29	<10	61	01	Tap fed by a Stream	01
		Gaw Ran	252	25	<10	106	01	Tap fed by a Spring	01
Upper Foot Hills (UFHs)-2,400-3,000	UFHs (2,400-3,000)	Raing Mandoo	143	14	<10	61	01	Spring	01
		Chuntwar	00	00	00	106	01	00	00
Total			1,283	128	10	-	06	-	05

Table 3. Sample Villages and Sample Sites with codes and geo-coordinates

Macro Regions (Altitudinal Zones in meters AMSL)	Micro Regions (Sub-altitudinal Zones in meters AMSL)	Sample Villages/Sites	Sample Village/Site (Codes)	Geo-Coordinates (Lat./Long.)
Lower Foot Hills (LFHs)-1,800-2,400	LFHs-1 1,800-2,100	Bidder Hayat Pora	SS1-ANG	$33^0$36'23" N & 75^0 17'54"E
		Bindoo Zalan Gam	SS2-ANG	33^0 34'45" N & 75^0 18'17"E
	LFHs-2 2,100-2,400	Hala Pora	SS3-ANG	33^0 30'40" N & $75^0$21'07"E
		Gaw Ran	SS4-ANG	$33^0$35'24" N & $75^0$21'26"E
Upper Foot Hills (UFHs)-2,400-3,000	UFHs 2,400-3,000	Raing Mandoo	SS5-ANG	33^0 26'38" N & 75^0 22'24"E
		Chuntwar	SS6-ANG	$33^0$34'15" N & 75^0 24'08"E

Source: SOI toposheets, 1971

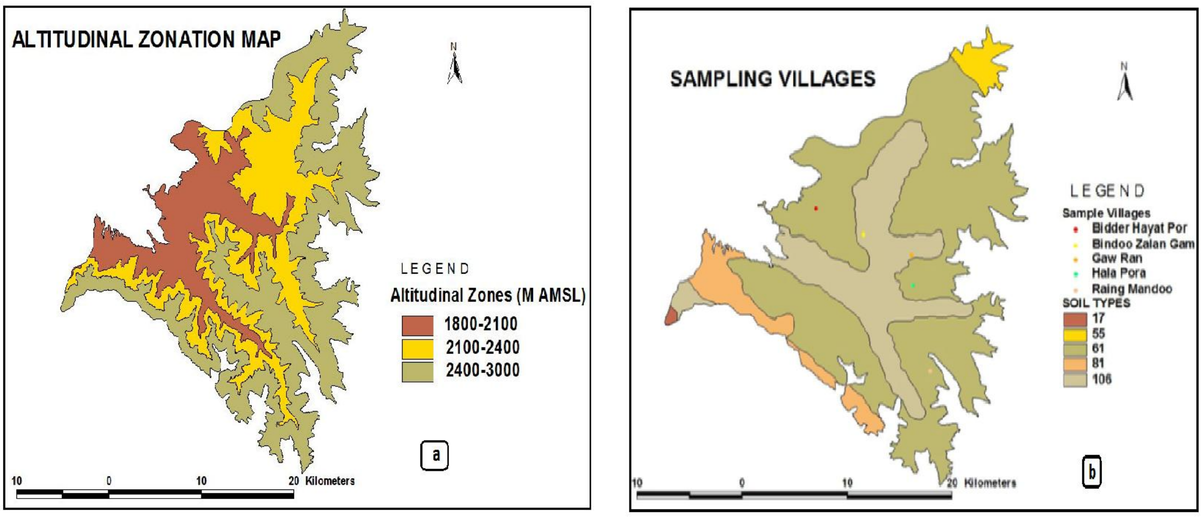

Figure 4. a) Altitudinal zonation map (generated from SOI toposheets, 1971), and b) Sampling villages

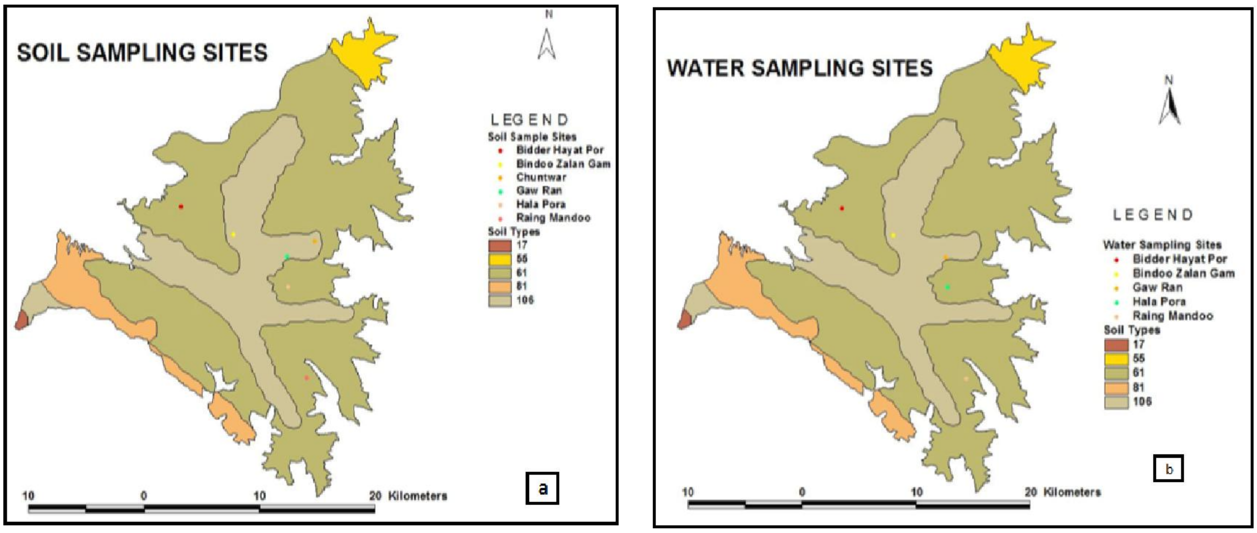

Figure 5. a) Soil Sampling Sites, and b) Drinking Water Sampling Sites

RESULTS AND DISCUSSION

Concentration of Zinc and Copper in the Soil and Drinking Water sources

The soils and drinking water sources of the foot hills of Pir Panjal range in Anantnag district are deficient in zinc and copper contents in all the altitudinal zones. The pH was found tending towards slight acidic character. The mean zinc, copper, pH and organic matter in the soils were found as 1.090 mg kg^{-1}, 1.539 mg kg^{-1}, 6.35 and 3.22% respectively. These parameters varied in mean values from LFHs to UFHs from 1.000-1.271 mg kg^{-1}, 1.787-1.539 mg kg^{-1}, 6.27-6.35 and 3.27-3.22% respectively. The mean zinc concentration showed negative relationship with organic matter and acidity. While as copper was found as positively related to organic matter. The variations were noted within the soil types (Table 4 and 5).

The soil type-61 registered high zinc content as compared to soil type-106 because the former is characterized by relatively more total organic matter. There is a net increase in zinc content with altitude in case of soil type-61 and decrease in case of soil type-106 (Table 4). The former case may be attributed to the increasing OM at the respective sites and the latter to the decreasing OM. The soil type-61 showed low copper content as compared to soil type-106 because the former is characterized by loamy skeletal texture and severe erosion while as the later is characterized by fine loamy texture and moderate erosion. There is a net decrease in copper content with altitude in both of the soil types for there is increase in slope, rainfall and coarser texture (soil texture becomes coarser with altitude). The decrease in copper content with altitude in soil-type-106 showed a good relationship with OM and pH. Therefore, it can be said that the cereals grown in these soils might be zinc and copper deficient leading to its deficiency in human beings especially where people are more dependent on locally cultivated food items.

Table 4. Concentration of Zinc, Copper, pH and Organic Matter in Soil types

Macro Regions	Micro Regions	Sample Sites	Soil Code	Zinc Conc. (mg kg-1)	Copper Conc. (mg kg-1)	pH	Organic Matter (%)
LOWER FOOT HILLS	LFHs-1 (1,800-2,100 m AMSL)	SS1-ANG	61	1.134	1.664	6.42	2.15
		SS2-ANG	106	0.798	2.270	6.51	3.76
	LFHs-2 (2,100-2,400 m AMSL)	SS3-ANG	61	1.332	1.558	6.28	3.76
		SS4-ANG	106	0.734	1.654	5.88	3.42
Mean				1.000	1.787	6.27	3.27
UPPER FOOT HILLS	UFHs (2,400-3,000 m AMSL)	SS5-ANG	61	1.972	0.930	6.42	4.90
		SS6-ANG	106	0.570	1.160	6.56	1.34
Mean				1.271	1.045	6.49	3.12
Mean				1.090	1.539	6.35	3.22
Standard Deviation				0.469	0.424	-	-
Coefficient of Variation				43.04%	27.5%	-	-

Source: Based on soil sample analysis done by the authors, 2013

Table 5. Concentration of Zinc, Copper and pH in Water sources

Macro Regions	Micro Regions	Sample Sites	Water Source	Zinc Conc. (mg L-1)	Copper Conc. (mg L-1)	pH
LOWER FOOT HILLS	LFHs-1 (1,800-2,100 m AMSL)	SS1-ANG	TSg	0.016	0.018	7.53
		SS2-ANG	TSm	0.025	0.012	7.85
	LFHs-2 (2,100-2,400 m AMSL)	SS3-ANG	TSm	0.075	0.012	7.87
		SS4-ANG	TSg	0.217	0.012	7.54
Mean				0.083	0.014	7.69
UPPER FOOT HILLS	UFHs (2,400-3,000 m AMSL)	SS5-ANG	Sg	0.093	0.016	7.75
		SS6-ANG	00	00	00	00
Mean				0.093	0.016	7.75
Mean				0.085	0.014	7.71
Standard Deviation				0.072	0.003	-
Coefficient of Variation				84.5%	18.1%	-

Source: Based on water sample analysis done by the authors, 2013

Table 5 highlights that Zn content in the drinking water sources of all types in all the altitudinal zones is more than the world average for their pH is relatively alkaline but less than the human requirement. At present, there is no health-based guideline value at world level for Zn though in 1984 it was established as 5 mg L^{-1} (WHO, 2006). But, BIS has given the same standard as above for Indian people. The sample site SS4-ANG records higher Zn content than other sample sites due to acidic regime of the surrounding soil. It is because that largest input to waters occurs from the surrounding soils. The concentration of Cu in water is highly dependent on the water pH. Likewise, the table 5 highlights that copper content in the drinking water sources in all the altitudinal zones is more than the world average (0.002 mg L^{-1}) for their pH is relatively alkaline. But, the Cu concentration in the drinking water sources is very less than the health-based guideline value of 2 mg L^{-1} (W.H.O., 2006) or 0.05 mg L^{-1} (BIS, 2009). Zinc and copper deficient drinking water, therefore, couples with the zinc and copper deficit foods and lead to resultant mineral deficiency in people with related ailments and disorders in the area.

Prevalence of Zinc and Copper deficiency diseases

The Table 6 shows the prevalence of zinc and copper deficiency diseases in the sample villages. About 3.1 % and 2.3 % of people in all the age-sex groups suffer from different zinc and copper deficiency disorders (table 6). The percentage prevalence of zinc and copper related ailments decreased from LFHs to UFHs from 3.3-1.6 % and 2.6-0.00 % with change in households using inappropriate cooking methods (deep and long period boiling, braising, blanching or frying) from 90.4-85.7 % respectively (Table 7). So, disease prevalence showed a positive relationship with the cooking methods. The variation in the prevalence of zinc and copper related disorders could not be discussed with certainty for several reasons. Some people are conservative and do not disclose reality during surveys. There is lack of absolute recording system in the hospitals. Moreover, people belong to different economic groups and treat their health related issues in different hospitals in vicinity or outside that. But, one thing can be put forward that the whole region is risk prone to these deficiency disease because of certain factors, one deficiency of the zinc and copper in soil and water, second greater dependence on local foods (vegetarian diet) (Figure 6a and b) because of financial condition (Table 8) and third inappropriate cooking methods.

Table 6. Prevalence of Zinc and Copper Deficiency diseases in altitudinal zones (by age & sex)

Macro Region	Micro Region	Sample Villages	Number of Persons Surveyed (100%)	Age Groups	Sex	Persons Suffering from Zinc Deficiency Disease (Diabetes)	Persons Suffering from Copper Deficiency Disease (Bone and Nerve ailments)
LFH	LFHs-1	SS1-	6	Children	M	1	0
		ANG	4	(1-14)	F	0	0
			8	Adults	M	0	0
			8	(15-50)	F	0	1
			1	Olds	M	0	0
			1	(>50)	F	1	0
		Total	28			2 (7.1)	1 (3.6)
		SS2-	36	Children	M	1	1
		ANG	40	(1-14)	F	1	0
			52	Adults	M	0	0
			52	(15-50)	F	2	1
			27	Olds	M	1	0
			23	(>50)	F	0	1
		Total	230			5 (2.3)	3 (1.3)
	Total		258			7 (2.7)	4 (1.5)
	LFHs-2	SS3-	14	Children	M	0	2
		ANG	9	(1-14)	F	1	0
			29	Adults	M	1	1
			28	(15-50)	F	2	2
			15	Olds	M	1	0
			15	(>50)	F	0	1
		Total	110			5 (4.5)	6 (5.5)
		SS4-	16	Children	M	1	0
		ANG	12	(1-14)	F	0	0
			25	Adults	M	0	0
			24	(15-50)	F	1	1
			7	Olds	M	1	1
			7	(>50)	F	0	0
		Total	91			3 (3.3)	2 (2.2)
	Total		201			8 (3.8)	8 (3.9)
Total			459			15 (3.3)	12 (2.6)
UFHs	UFHs	SS5-	14	Children	M	0	0
		ANG	11	(1-14)	F	1	0
			14	Adults	M	0	0
			14	(15-50)	F	0	0
			5	Olds	M	0	0
			5	(>50)	F	0	0
	Total		63			1 (1.6)	0 (0.0)
Grand Total			522			16 (3.1)	12 (2.3)

Note: Values in parenthesis show percentage to respective total persons surveyed
Source: Data collected by Authors through sample survey

Table 7. Households Drinking Boiled Water, Dependence of People on Locally Cultivated Food Items and Methods of Cooking

Macro Region	Micro Region	Sample Villages	No. of Households Surveyed (100%)	Households Drinking Boiled Water (%)	Households Dependent on Local food items (%)		Food Purchased from Market (%)	Methods of cooking foods (%)	
					<50%	>50%		Deep[1]	Light[2]
LFHs	LFHs-1	SS1-ANG	8	6(75)	37.5	62.5	37.8	8(100)	0(0)
		SS2-ANG	52	35(67.3)	00	100	23.85	50(96.2)	2(3.8)
	Total		60	41(68.3)	18.75	81.25	30.83	58(96.7)	2(3.3)
	LFHs-2	SS3-ANG	29	14(48.3)	3.45	96.55	30.17	25(86.2)	4(13.8)
		SS4-ANG	25	10(40)	32	68	43.00	20(80.0)	5(20.0)
	Total		54	24(44.4)	17.73	82.27	36.58	45(83.4)	9(16.6)
	Total		114	65(57.02)	18.24	81.76	33.71	103(90.4)	11(9.6)
UFHs	UFHs	SS5-ANG	14	0(00)	7.14	92.85	32.5	12(85.7)	2(14.3)
	Grand Total		128	65(50.7)	12.69	87.31	33.11	107(93.8)	13(6.2)

Source: Field Survey (conducted by the authors), 2013

Note: Deep[1]=Long period Boiling/Braising/Blanching/Frying, Light[2]=Short period Boiling/Braising/Blanching/Frying

Table 8. Income Levels of Households Surveyed (Rs. %)

Macro Region	Micro Region	Sample Villages	Number of Households Surveyed (100%)	Average Family Size (numbers)	Income Levels of Households Surveyed (Rs.%)		
					Low (<5, 000)	Medium (5, 000-10, 000)	High (>10, 000)
LFHs	LFHs-1	SS1-ANG	8	6	2 (25.0)	2 (25.0)	4 (50.0)
		SS2-ANG	52	7	8 (15.4)	24 (46.1)	20 (38.5)
		Total	60	6.5	10 (16.7)	26 (43.3)	24 (46.0)
	LFHs-2	SS3-ANG	29	7	6 (20.7)	10 (34.4)	13 (44.9)
		SS4-ANG	25	6.5	5 (20.0)	10 (40.0)	10 (40.0)
		Total	54	6.75	11 (20.4)	20 (37.0)	23 (42.6)
	Total		114	6.63	21 (18.4)	46 (40.4)	47 (41.2)
UFHs	UFHs	SS5-ANG	14	7.3	4 (28.6)	9 (64.3)	1 (7.10)
	Grand Total		128	6.96	25 (19.5)	55 (42.9)	48 (37.6)

Source: Field Survey (conducted by the authors), 2013

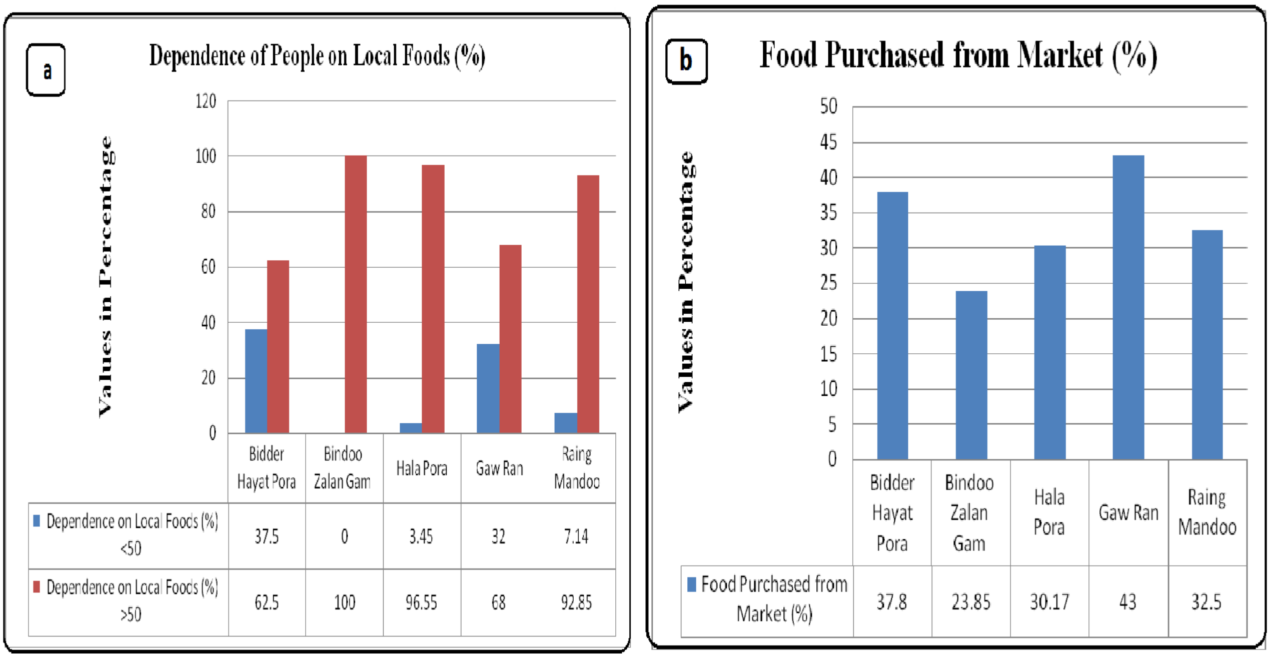

Figure 6. a) Dependence on Local foods (%) and b) Food purchased from Market (%)
(Data collected through field survey by the authors, 2013)

Conclusion

- The study leads to the conclusion that Zn and Cu content in all the soil sample sites (SS1-ANG, SS2-ANG, SS3-ANG, SS4-ANG, SS5-ANG, and SS6-ANG) is less than the world level averages of Zn and Cu in soils but more in fresh (drinking) water sources in all the altitudinal zones than world averages.
- Zn concentration is more in soil type-61 (typic udorthents-dystric eutrochrepts) than soil type-106 (dystric eutrochrepts-lithic udorthents) in all the sub-zones and reverse is true for Cu.
- Another observation is that Zn concentration showed a close association with organic matter and pH. Cu content in soils showed a close association with soil texture.
- The percentage prevalence of Zn deficiency diseases (3.1 %) was found greater than copper related disorders (2.3 %) since Zn and Cu have antagonistic relationship in human body.
- The deficiency of Zn and Cu in the soils and drinking waters, greater dependence on local foods and inappropriate cooking methods are some of the key factors that contribute to the geo-ecology of the Zn and Cu deficiency diseases in the study area.

Suggestions

- Modification of soil culture through application of Zn and Cu rich fertilizers such as like Cu SO_4 $5H_2O$ (Copper Sulphate) for Cu deficiency and $ZnSO_4$ 7 H_2O (Zinc Sulphate) for Zn deficiency, either as foliar spray or directly in the soil (Kaleem, 1991), but in accordance with deficiency, as mega dose of Zn and Cu above the standard requirement can induce Cu imbalance further. So far as the cropping pattern in the area is concerned, variability of trace element signifies a need of change in the cropping pattern of the study area.
- Change in diet i.e., required use of Zn and Cu rich foods meat, fish, dry fruits and dairy products that are rich in Zn and Cu nutrients.
- Food processing strategies such as germination, microbial fermentation and malting be employed for enhancing the absorption of Zn and Cu.
- Choice of appropriate cooking methods such as light frying, light boiling without discarding water, addition of salt to the food during cooking, pressure cooking, and the like.

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Geomedical study of thyroid disorders in the foot hill settlements of Pir Panjal Range

Rafiq Ahmad Hajam*, Ghulam Mohmad Rather and Tasawoor Ahmed Kanth

Department of Geography and Regional Development, University of Kashmir, Srinagar, India.

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The present study is an, attempt to find out the concentration of Iodine (I) in soil and water phases of the natural environment, and its relationship with the human health in the foot hill settlements of Pir Panjal Range in Anantnag district of Kashmir valley. Also, socio-economic determinants of health were taken into due account. Firstly, the area was divided into altitudinal zones and soils classes. Then, the soil and water samples were taken from each soil type in each altitudinal zone and were analyzed by Atomic Absorption Spectrophotometer. The socio-economic character of the area was analyzed through surveying the area by using structured household schedules. In this area, people rely mostly on locally cultivated food items because of their economic condition. The study highlights that about 19.5, 42.9 and 37.6% households in the study area have low (Rs. <5, 000 month^{-1}), medium (Rs. 5, 000-10, 000 month^{-1}) and high (Rs. >10, 000 month^{-1}) income status respectively. The study reveals that iodine content in all the soil (0.970 to 1.230 mg kg^{-1}) and water (1.6 to 4.2 µg L^{-1}) samples in all the altitudinal zones is less than the average values in the world soils (2.8 mg kg^{-1}) and fresh waters (8.7 µg L^{-1}). About 17.6% of the population in sample villages suffers from Iodine Deficiency Disorders (IDDs). These IDDs can be ascribed to the scarcity of iodine in soils, drinking waters (and hence diet) and lifestyle. Attempts have been made to suggest certain remedial measures to minimize the magnitude of IDD sufferers in the study area.

Key words: Iodine, thyroid disorders, foot hills, cooking methods.

INTRODUCTION

Trace elements are the elements present in the earth's crust in concentrations less than 0.1% (<1000 mg kg^{-1}) or those elements that are ordinarily present in plant or animal including human beings tissues in concentrations less than 0.01% (<100 mg kg^{-1}) of the organism's dry weight (Adriano, 2001). Trace elements are necessary for life in small amounts. They are components of haemoglobin, Deoxyribonucleic acid, Ribonucleic acid, and various enzymes (Warren, 1991). Trace metals play an important role in the synthesis of both proteins and nucleic acids. There is a standard requirement of each trace element for human health (WHO, 1996). All essential trace elements either in excess states or in deficit states are known to create serious health problems particularly in the areas where these are regionally deficit (Hunter and Akhtar, 1991) or surplus. The

*Corresponding author. E-mail: rafiqahmad70@gmail.com; Tel:09797127509.

concentration of trace elements in soil, water or food items is mainly determined by the geological conditions of the area (Keller, 1999; Pyle, 1979).

The human body does not make its own iodine and is dependent on dietary sources, and thus making it an essential part of our diet. The healthy adult human body contains 15 to 20 mgs of iodine, of which about 70 to 80% is in the thyroid gland. The normal intake and requirement of iodine is 100 to 150 µg d^{-1} (Masoodi, 2012; Fuge, 2005).

It is an essential element that is critical for the normal growth and development, and well being of all humans. Iodine deficiency is associated with reduced thyroid hormone synthesis, leading to increased thyroid stimulating hormone levels, which stimulates thyroid over growth and goiter (Jamescon and Weetman, 2005). The distribution of iodine is uneven in the biosphere. Its deficiency does not cause a mere enlargement of thyroid gland (endemic goiter), it can cause a variety of disorders called iodine deficiency disorders (IDDs) or thyroid disorders consisting of hypothyroidism, endemic cretinism, still-births, mental retardation, defects in vision, hearing and speech, and neuromuscular weakness.

These disorders are mainly found in those people who live away from coastal areas, in mountainous areas, previously glaciated areas and the like. Even people living in coastal areas and on islands suffer from IDDs because sea salt does not contain iodine content as much as required by the people and due to their unsuitable habits (UNICEF, 2002). World health organisation estimated that about 20 to 60% of the world's population is iodine deficient (Zimmermann, 2009) with most of the burden in developing countries. Mayer while working out the goiter incidence in Kashmir Valley during 2004 to 2005 found that Anantnag district (a part of foot hills) has the highest incidence of goiter, and he suggested that nature of bedrock and soils is responsible for the variable goiter incidence in the valley.

According to a recent research conducted on school children of Kulgam district which is a part of the foot hills of Pir Panjal range, it was found that 18.9% suffer from Total Goiter Rate (TGR); 21.2% boys and 16.7% girls (Khan et al., 2014). Since, the incidence/prevalence of thyroid disorders is a significant health problem covering an appreciable section of the society in the foot hills of Pir Panjal range, the present study was attempted to investigate its the possible causes and factors of both geochemical and socio-economic origins in the area.

Study area

The area taken in this study is a part of the Kashmir region located roughly between the elevations of 1,800 meters to 3,000 meters above the mean sea level (m AMSL). The area lies between 33°23´ 08" N to 332°65´90" N latitudes and 74° 55 75° 10' 05'' to 75° 35′ 20'' E longitudes, covering an area of about 547.04 km^2 (Figure 1) with a population of about 1, 88,055 (Census, 2011). The soils of the concerned area vary in origin from alluvial to lacustrine and glacial (Figure 2 and Table 1).

METHODOLOGY

A comprehensive methodology has been adopted to carry out the present study. Figure 3 shows the general data base and methodological scheme divided into many related steps in order to accomplish the objectives of the present work.

GIS techniques

The study area was delineated from Survey of India (SOI) toposheets of 1:50,000 scale of 1971 with numbers as 43 O/2, 43 O/3, 43 O/6 and 43 O/7 with the help of Arc View 3.2a software. The base contour was taken as 1,800th m AMSL and top one as 3,000th m AMSL (Raza et al., 1978). These two contours were connected on the lateral sides by taking the watershed limits through digitization.

By digitizing 2,400th m contour, the area under study was divided into two altitudinal zones, namely, Lower Foot Hills (LFHs) and Upper Foot Hills (UFHs) varying in altitude from 1,800th-2,400th m and 2,400th-3,000th m respectively. The LFHs are characterized by good permanent human occupancy, while as the UFHs experience mostly seasonal human inhabitations. By digitizing 2,100th m contour, the LFHs were further sub-divided into two sub-zones namely, LFHs-1 and LFHs-2 varying in elevation from 1,800th-2,100th m and 2,100th-2,400th m (Figure 4a) for comparative analysis.

Stratified random sampling technique was used for the selection of sample sites (sample villages, soil and water sample sites), and sample households as shown in Tables 2 and 3 and Figures 4b, 5a and 5b.

Field Work

The soil samples were collected in clean unused polythene bags and were labeled properly. A clean spade was used to take the soil samples. In order to reduce variability, a composite sample was obtained from each sample site. A composite sample comprised of five sub-samples taken from each sample site in 10 m × 10 m grid format. Four sub-samples were taken from four corners of the square and one from the center. Soil samples were taken from depths of 0 to 20, 0 to 40 and 0 to 60 cm in relation to different major land uses that is, agricultural, horticultural and forest respectively (Brady, 1991; Pennock et al., 2008). Water samples were collected in clean unused plastic bottles from the selected sample sites and were labeled properly, and were taken to the lab within 24 h. Both types of samples were analyzed in Research Centre for Residue and Quality Analysis Lab, SKUAST, Shalimar. The socio-economic survey was done through the structured schedules to give the socio-economic picture of the area and to assess the dependence of people on local food items, income status, methods of cooking, households using iodized salt and boiled drinking water and percentage of households purchasing food from the market. The data regarding the prevalence of IDDs was collected from the prescriptions given by the registered practitioners.

Lab work

The soil samples were air-dried, crushed with a wooden roller,

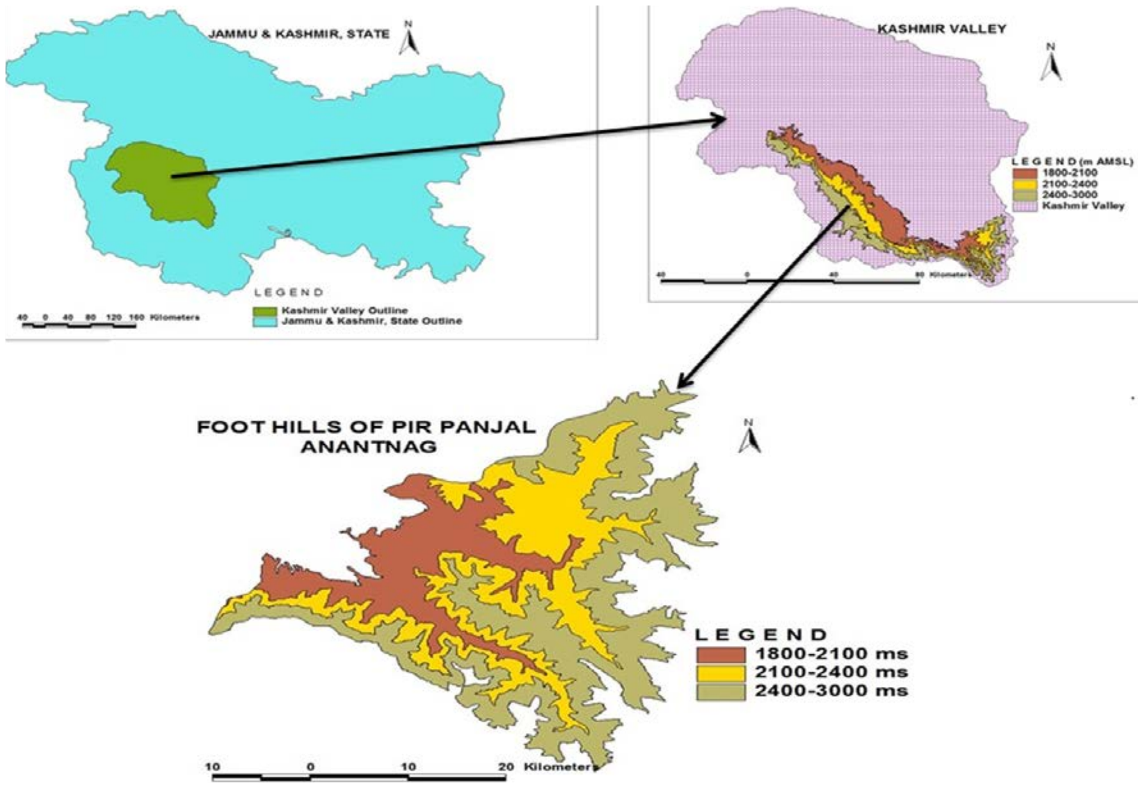

Figure 1. Location map of foot hills of Pir Panjal range in Anantnag (Generated from SOI toposheets, 1971).

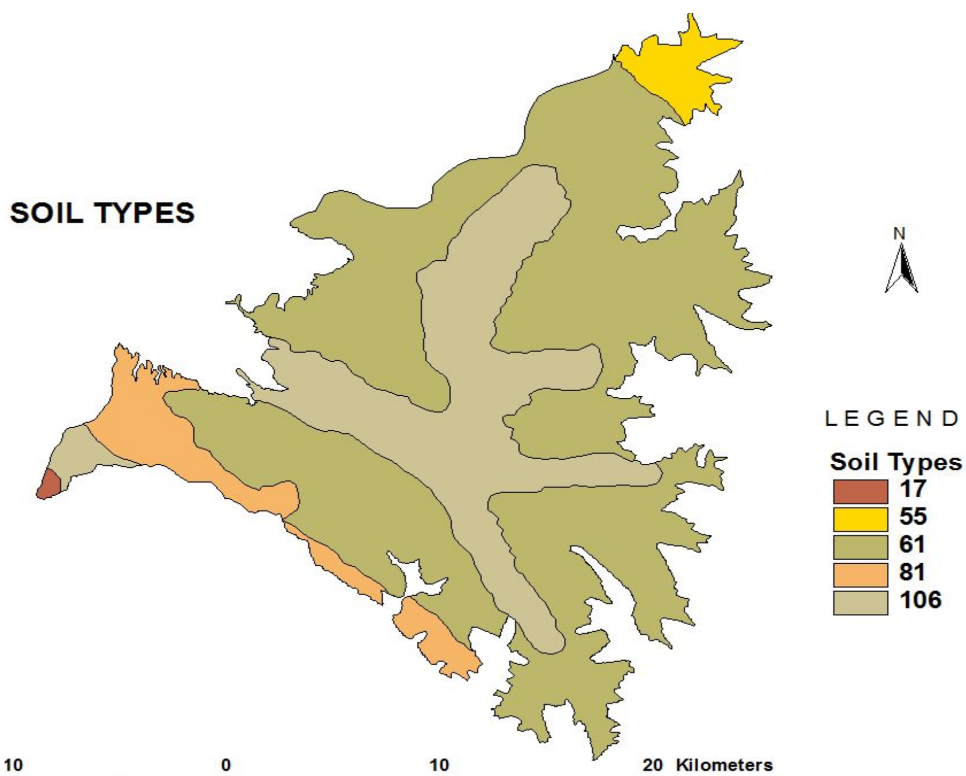

Figure 2. Soil map of the study area (Generated from Soil Map of J & K, ICAR, Nagpur-2010).

Table 1. Soil types with codes and description.

Code	Description	Soil type
17	Dominantly rock outcrops; associated with shallow, loamy, calcareous soils on steep to very steep slopes with loamy surface, strong stoniness and severe erosion	Lithic. Cryorthents
55	Deep, well drained coarse-loamy soils on gentle slopes with loamy surface, moderate erosion and slight gravelliness; associated with deep, well drained, coarse loamy, calcareous soils with loamy surface, moderate erosion and slight gravelliness	Typic Cryofluvents
61	Medium deep, well drained, loamy-skeletal soils on moderate slopes with loamy surface, severe erosion and strong stoniness; associated with medium deep, well drained, fine-loamy soils with loamy surface, moderate erosion and moderate stonniness.	Typic Udorthents/ Dystric Eutrochrepts
81	Deep, moderately well drained, fine soils on very gentle slopes with loamy surface; associated with deep, well drained, fine-loamy soils with loamy surface	Typic Hapludalfs/ Dystric Eutrochrepts
106	Medium deep, well drained, fine loamy soils on moderate slopes with loamy surface and moderate erosion; associated with shallow, excessively drained, loamy soils with loamy surface, moderate erosion and strong stonniness	Dystric Eutrochrepts/ Lithic Udorthents

Source: Modified from Soil Map of J & K, ICAR, Nagpur-2010.

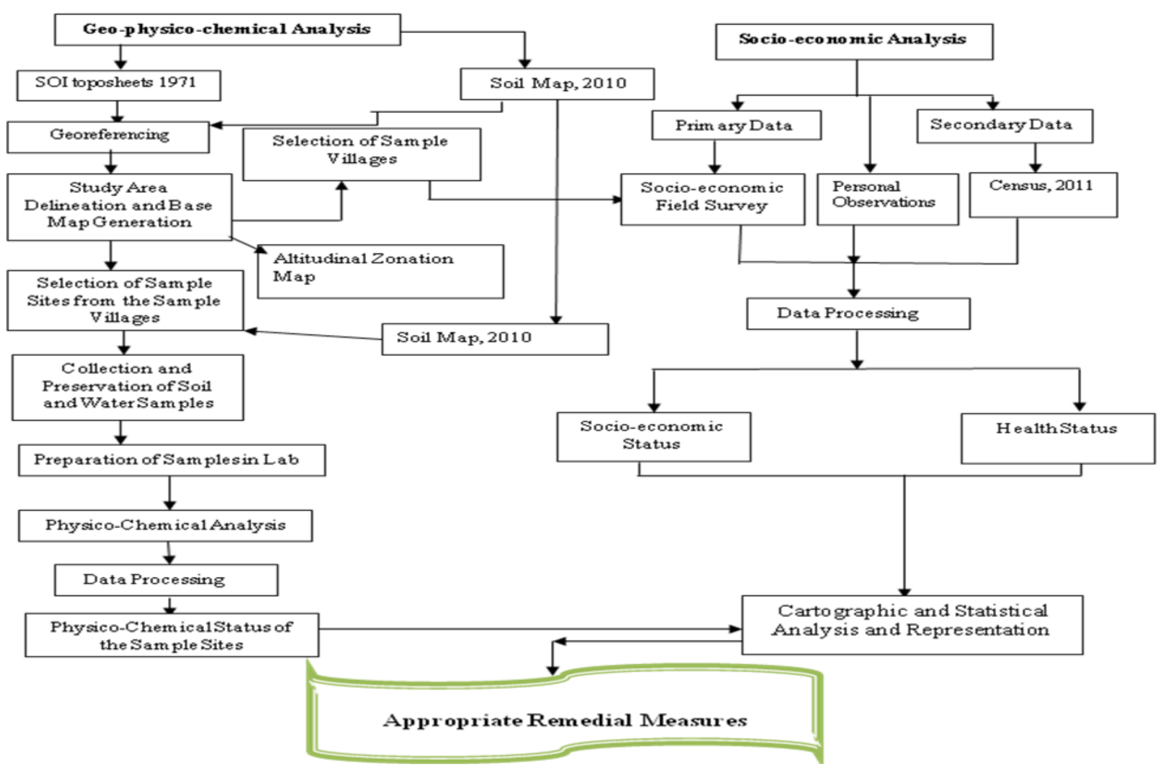

Figure 3. Flow chart of methodology.

passed through a 10 mesh (<2 mm) sieve, and then ground in an agate mortar. The recovered <63 μm particles were separated for chemical analysis. The samples were analyzed under Atomic Absorption Spectrophotometer (AAS-4141, Electronic Corporation

Table 2. Sample frame.

Macro regions (Altitudinal zones in meters AMSL)	Micro regions (Sub-altitudinal zones in meters AMSL)	Sample villages	Total No. of households in the sample villages	Number of households Surveyed	Percentage of surveyed Households to total Households	Soil type (Codes)	Number of samples taken	Main water source	No. of samples taken
Lower foot hills (LFHS)-1,800-2,400	LFHs-1 (1,800-2,100)	Bidder Hayat Pora	77	08	>10	61	01	TSg	01
		Bindoo Zalan Gam	519	52	>10	106	01	TSm	01
	LFHs-2 (2,100-2,400)	Hala Pora	292	29	<10	61	01	TSm	01
		Gaw Ran	252	25	<10	106	01	TSg	01
Upper foot hills (UFHs)-2,400-3,000	UFHs (2,400-3,000)	Raing Mandoo	143	14	<10	61	01	Sg	01
		Chuntwar	00	00	00	106	01	00	00
Total	-	-	1,283	128	10	-	06	-	05

Source: Generated by the authors.

Table 3. Sample villages and sample sites with codes and geo-coordinates.

Macro regions (Altitudinal zones in meters AMSL)	Micro regions (Sub-altitudinal zones in meters AMSL)	Sample villages/sites	Sample village/site (Codes)	Geo-coordinates (Lat./Long.)
Lower Foot Hills (LFHs)-1,800-2,400	LFHs-1 1,800-2,100	Bidder Hayat Pora	SS1-ANG	33°36'23° N & 75° 17'54"E
		Bindoo Zalan Gam	SS2-ANG	33° 34'45°N & 75° 18'17"E
	LFHs-2 2,100-2,400	Hala Pora	SS3-ANG	33° 30'40°N & 75° 21'07"E
		Gaw Ran	SS4-ANG	33°35'24°N & 75° 21'26"E
Upper Foot Hills (UFHs)-2,400-3,000	UFHs 2,400-3,000	Raing Mandoo	SS5-ANG	33° 26'38°N & 75° 22'24"E
		Chuntwar	SS6-ANG	33°34'15°N & 75° 24'08"E

Source: SOI toposheets, 1971.

Limited, India). A total concentration of I was determined after 4-acid digestion (HF, $HClO_4$, HNO_3 and HCl) by AAS. The samples were analyzed for iodine, pH and organic matter (OM).

RESULTS AND DISCUSSIONS

Concentration of Iodine in the soil and drinking water sources

The study showed that the soils and drinking water sources of the foot hills of Pir Panjal range in Anantnag district are deficient in iodine content in all the altitudinal zones (Tables 4 and 5), and have iodine content less than the world averages.

From Table 4, it is obvious that the soils are iodine deficient at all the elevation levels in the study area. The organic matter and pH influence the concentration of iodine in the soils. In soil type-61, iodine content first increases with altitude because of increase in OM in the soil, and then slightly decreases with altitude due to increasing slope and coarser texture of soil. OM binds up iodine ions in the soil but the increasing slope and coarser texture cause iodine ions flow and translocate easily during rainfalls. In soil type-106, iodine content first decreases with altitude because of increase in the acidity of the soil and then increases with altitude. The acidic pH in soil catalyzes the loss of iodine ions in soil through leaching.

Likewise, Table 5 shows the concentration of iodine in drinking water sources in the area. Iodine content in drinking water sources first increases with altitude and then decreases. It shows affinity

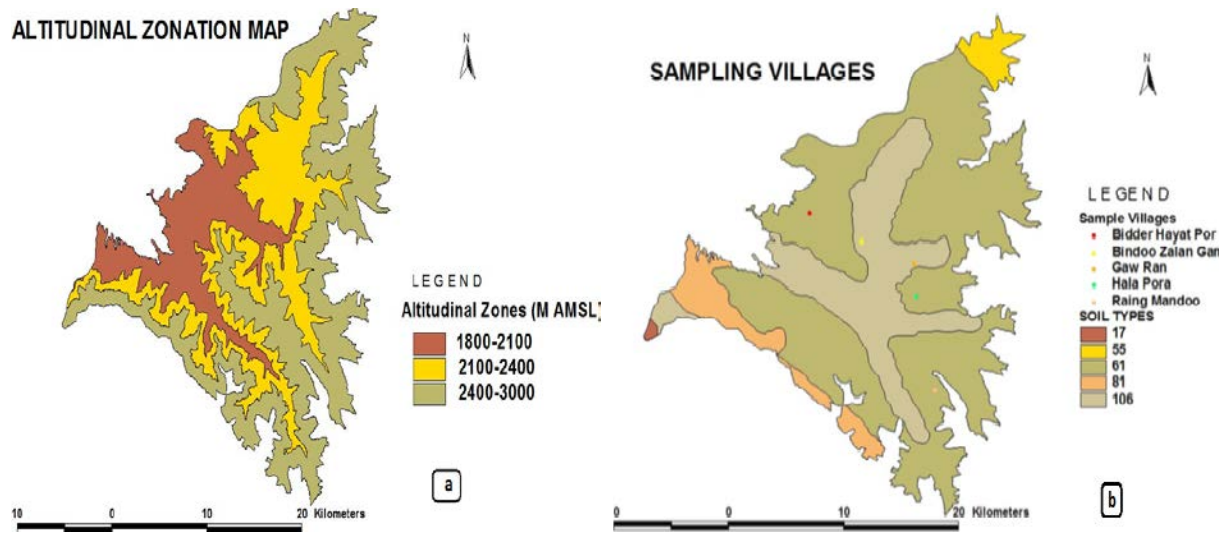

Figure 4. (a) Altitudinal zonation map and (b) Sampling villages.

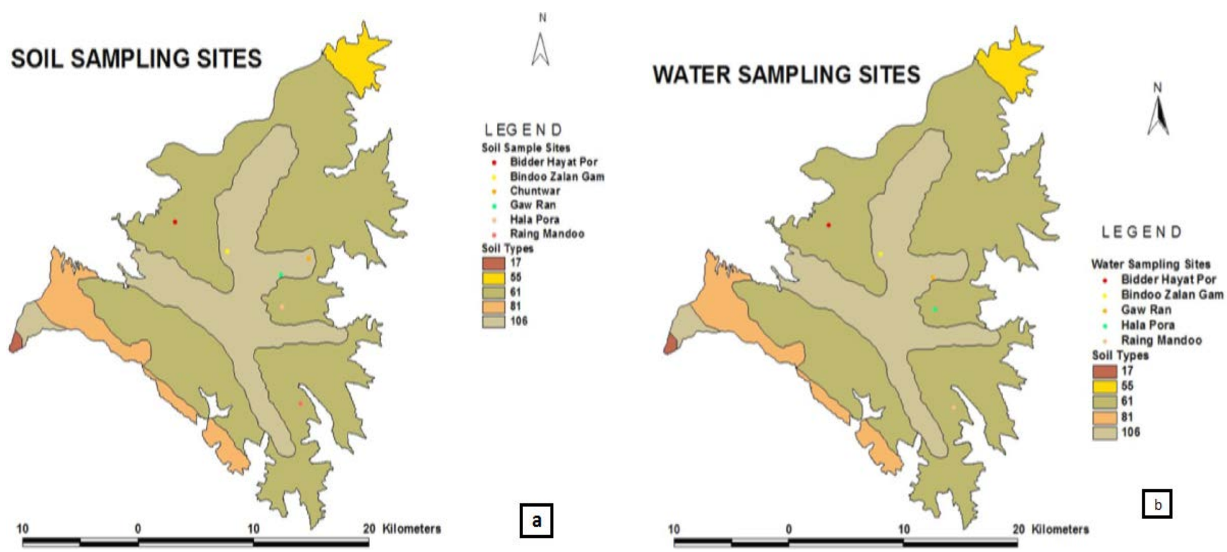

Figure 5. (a) Soil Sampling Sites and (b) Drinking water sampling sites.

to the surrounding soils and their physico-chemical character.

Prevalence of Iodine deficiency diseases

The study revealed that about 17.6% people suffer from different IDDs in all the age-sex groups (Table 6). These people have greater (66.89%) dependence on locally cultivated food items because of their disadvantaged economic condition. More than 62.4% households comprising low and medium income status households fall below poverty line as per international standards of income-based poverty lines (Rs. 2371.5 month^{-1} person^{-1}). They also have inadequate income as per the local economic scenario is concerned.

It is evident from the Table 6 that in the sample village of UFH region, about 30.2% people suffer from IDDs as compared to 24.0% of LFH region. This variation can be attributed to the greater dependence of people on locally cultivated iodine deficit food items, and less use of iodized salt in UFHs than the people in LFHs (Table 7). In the sample village in UFHs, about 92.9% households fall in low and medium income groups (Table 8) which forces them to rely on whatever food items they cultivate locally. About 92.85% households have >50% dependence on

Table 4. Iodine content, pH and organic matter of soil types.

Macro regions	Micro regions	Sample sites	Soil type	Iodine conc. (mg kg^{-1})	pH	Organic matter (OM in %)
Lower foot hills	LFHs-1 (1,800-2,100 m AMSL)	SS1-ANG	61	0.980	6.42	2.15
		SS2-ANG	106	1.000	6.51	3.76
	LFHs-2 (2,100-2,400 m AMSL)	SS3-ANG	61	1.230	6.28	3.76
		SS4-ANG	106	0.970	5.88	3.42
Mean				1.05	6.27	3.27
Upper foot hills	UFHs (2,400-3,000 m AMSL)	SS5-ANG	61	1.050	6.42	4.90
		SS6-ANG	106	1.000	6.56	1.34
Mean	-	-	-	1.03	6.49	3.12
Mean	-	-	-	1.04	6.35	3.22
Standard deviation	-	-	-	0.0893mg kg^{-1}	-	-
Coefficient of SD	-	-	-	0.0859	-	-
Coefficient of variation	-	-	-	8.6003%	-	-

Source: Based on soil sample analysis done by the authors, 2013.

Table 5. Iodine content and pH of water sources.

Macro regions	Micro regions	Sample sites	Water source	Iodine Conc. (µg L^{-1})	pH
Lower foot hills	LFHs-1 (1,800-2,100 m AMSL)	SS1-ANG	TSg	1.6	7.53
		SS2-ANG	TSm	2.5	7.85
	LFHs-2 (2,100-2,400 m AMSL)	SS3-ANG	TSm	3.9	7.87
		SS4-ANG	TSg	4.2	7.54
Mean				3.05	7.70
Upper foot hills	UFHs (2,400-3,000 m AMSL)	SS5-ANG	Sg	4.1	7.75
Mean	-	-	-	4.1	7.75
Mean	-	-	-	3.26	7.71
Standard Deviation	-	-	-	1.6600 µg L^{-1}	-
Coefficient of SD	-	-	-	0.5092	-
Coefficient of Variation	-	-	-	50.920%	-

Source: Based on water sample analysis done by the authors, 2013, Note: TSg=Tap fed by a spring, TSm=Tap fed by a stream, Sg=Spring.

local iodine deficit foods, and 42.8% people used iodized salt in UFHs as compared to the LFHs in which about 81.76% households in the sample villages have >50% reliance on local foods and 75.4% people use iodized salt (Table 7).

The prevalence of IDDs in LFHs shows a decline from LFHs-1 to LFHs-2. About 17.4% people suffer from IDDs in LFHs-1 as compared to 16.4% in LFHs-2 (Table 6). This variation seems to be outcome of the differential lifestyles especially the food cooking methods. In LFHs-1, about 96.7% households surveyed are accustomed to inappropriate cooking methods such as long period boiling, braising, blanching and frying as compared to LFHs-2 in which the value is 83.4% (Table 7).

The prevalence of IDDs in the sample villages in the sub-zones decreases with altitude with respect to changing iodine, pH and OM content in the respective soil types and socio-economic conditions with the exception of SS5-ANG. In the LFHs-1, SS1-ANG (soil type-61) records 21.4% and SS2-ANG (soil type-106) records 16.9% of patients and in LFHs-2, SS3-ANG (soil type-61) records 16.4% and SS4-ANG (soil type-106) records 16.5% of patients and in UFH sub-zone, SS5-ANG (soil type-61) experiences 22.2% of patients to its

Table 6. Prevalence of IDDs in different altitudinal zones (by age and sex).

Macro region	Micro region	Sample villages	Number of persons surveyed (100%)	Age groups	Sex	Number of persons suffering from IDDs (% cases to total)	
						Person suffering from IDD (Thyroid)	Person suffering from no IDD
LFH	LFHs-1	SS1-ANG	6	Children (1-14)	M	1 (16.6)	5 (83.4)
			4		F	1 (25)	3 (75)
			8	Adults (15-50)	M	2 (25)	6 (75)
			8		F	2 (25)	6 (75)
			1	Olds (>50)	M	0 (0)	1 (100)
			1		F	0 (0)	1 (100)
		Total	28	-	-	6 (21.4)	22 (79.6)
		SS2-ANG	36	Children (1-14)	M	7 (19.4)	29 (80.6)
			40		F	8 (20.0)	32 (80.0)
			52	Adults (15-50)	M	7 (13.5)	45 (86.5)
			52		F	9 (17.3)	43 (82.7)
			27	Olds (>50)	M	3 (13.1)	20 (86.9)
			23		F	5 (18.5)	22 (81.5)
		Total	230	-	-	39 (16.9)	191 (83.1)
	Total	-	258	-	-	45 (17.4)	213 (82.6)
	LFHs-2	SS3-ANG	14	Children (1-14)	M	3 (21.4)	11 (78.6)
			9		F	1 (11.1)	8 (88.9)
			29	Adults (15-50)	M	5 (17.2)	24 (81.8)
			28		F	5 (17.8)	23 (82.2)
			15	Olds (>50)	M	2 (13.4)	13 (85.6)
			15		F	2 (13.4)	13 (85.6)
		Total	110	-	-	18 (16.4)	92 (83.6)
		SS4-ANG	16	Children (1-14)	M	3 (18.7)	13 (81.3)
			12		F	1 (8.4)	11 (91.6)
			25	Adults (15-50)	M	4 (16.0)	21 (84.0)
			24		F	5 (20.8)	19 (79.2)
			7	Olds (>50)	M	1 (14.3)	6 (85.7)
			7		F	1 (14.3)	6 (85.7)
		Total	91	-	-	15 (16.5)	76 (83.5)
	Total	-	201	-	-	33 (16.4)	168 (83.6)
Total	-	-	459	-	-	78 (17.0)	381 (83.0)
UFHs	UFHs	SS5-ANG	14	Children (1-14)	M	3 (21.4)	11 (78.6)
			11		F	2 (18.2)	9 (81.8)
			14	Adults (15-50)	M	4 (28.6)	10 (71.4)
			14		F	2 (14.3)	12 (85.7)
			5	Olds (>50)	M	2 (40)	3 (60.0)
			5		F	1 (20)	4 (80.0)
Total			63	-		14 (22.2)	49 (77.8)
Grand total			522	-		92 (17.6)	430 (82.4)

Source: Sample survey, 2013.

Table 7. Showing households drinking boiled water, households using iodized salt, dependence of people on locally cultivated food items and methods of cooking.

Macro region	Micro region	Sample villages	Number of households surveyed (100%)	Households drinking boiled water (%)	Households using iodized salt (%)	Dependence on local food items (%)		Food purchased from market (%)	Methods of cooking foods (%)	
						<50%	>50%		Deep[1]	Light[2]
LFHs	LFHs-1	SS1-ANG	8	6 (75)	6 (75.0)	37.5	62.5	37.8	8 (100)	0 (0)
		SS2-ANG	52	35 (67.3)	40 (76.9)	00	100	23.85	50 (96.2)	2 (3.8)
	Total	-	60	41 (68.3)	46 (76.7)	18.75	81.25	30.83	58 (96.7)	2 (3.3)
	LFHs-2	SS3-ANG	29	14 (48.3)	19 (65.5)	3.45	96.55	30.17	25 (86.2)	4 (13.8)
		SS4-ANG	25	10 (40)	21 (84.0)	32	68	43.00	20 (80.0)	5 (20.0)
	Total	-	54	24 (44.4)	40 (74.1)	17.73	82.27	36.58	45 (83.4)	9 (16.6)
Total		-	114	65 (57.02)	86 (75.4)	18.24	81.76	33.71	103 (90.4)	11 (9.6)
UFHs	UFHs	SS5-ANG	14	0 (00)	6 (42.8)	7.14	92.85	32.5	12 (85.7)	2 (14.3)
Grand total		-	128	65 (50.7)	92 (71.8)	12.69	87.31	33.11	107 (93.8)	13 (6.2)

Source: Sample survey, 2013; Note: Deep[1]=Long period Boiling/Braising/Blanching/Frying, Light[2]=Short period Boiling/Braising/Blanching/Frying.

Table 8. Income levels of households surveyed (Rs. %).

Macro region	Micro region	Sample villages	Number of households surveyed (100%)	Average family size (numbers)	Income levels of households surveyed (Rs.%)		
					Low (<5, 000)	Medium (5, 000-10, 000)	High (>10, 000)
LFHs	LFHs-1	SS1-ANG	8	6	2 (25.0)	2 (25.0)	4 (50.0)
		SS2-ANG	52	7	8 (15.4)	24 (46.1)	20 (38.5)
		Total	60	6.5	10 (16.7)	26 (43.3)	24 (46.0)
	LFHs-2	SS3-ANG	29	7	6 (20.7)	10 (34.4)	13 (44.9)
		SS4-ANG	25	6.5	5 (20.0)	10 (40.0)	10 (40.0)
		Total	54	6.75	11 (20.4)	20 (37.0)	23 (42.6)
Total			114	6.63	21 (18.4)	46 (40.4)	47 (41.2)
UFHs	UFHs	SS5-ANG	14	7.3	4 (28.6)	9 (64.3)	1 (7.10)
Grand total			128	6.96	25 (19.5)	55 (42.9)	48 (37.6)

Source: Sample survey, 2013.

total surveyed population. The increase in the percentage of patients suffering from IDDs in SS5-ANG is due to high (4.90%) OM in soil (Table 4).

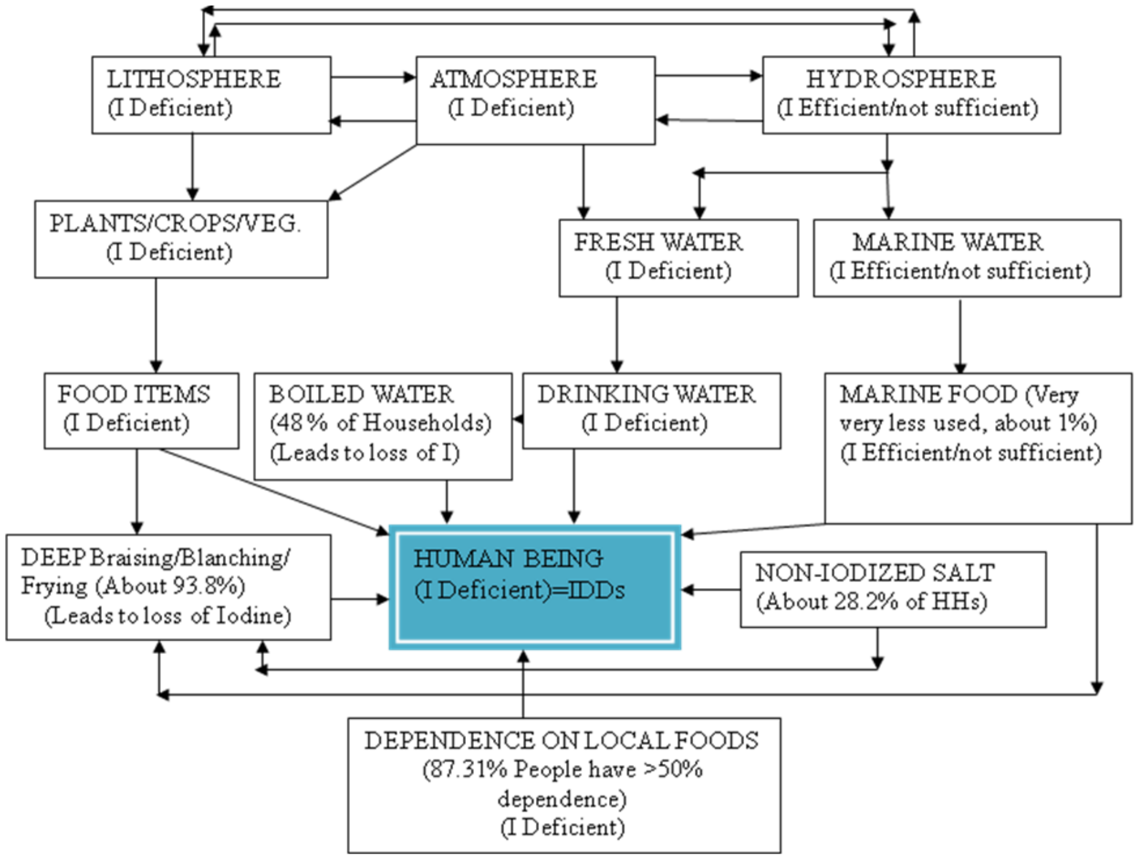

Figure 6. Schematic diagram showing transfer and loss of iodine at different stages of iodine transfer and the consequent results in human beings (Developed by the authors).

Though the concentration of iodine at SS5-ANG is relatively greater than some of the other sites, it has the disadvantage of having high OM. The OM decreases the bioavailability of iodine for the plants/crops resulting in iodine deficient foods. It may also be attributed to the greater dependence of the people on local foods (Table 7). Difference in the percentage prevalence of IDDs with respect to age and sex groups can be attributed to the relative differences in the life styles.

A diagrammatic model (Figure 6) has been developed related to the present study that shows cyclic movement of the iodine in the different phases of environment, the pathways on how iodine reaches the human body, its losses at different stages of movement at the dual hands of nature and humankind and the consequent results that is, IDDs. The diagram also highlights the role of natural pools of iodine transfer and the life style of the people of the area under study in contributing the causation of the different IDDs. The lithospheric and atmospheric pools of natural environment are iodine deficient while as the hydrospheric pool is efficient in iodine content but not sufficient to save human beings from IDDs. So, the food derived from the soil is deficient in iodine. An individual human being derives only about 0.5 µg d^{-1} of iodine from inhalation (Nordic Project Group, 1995). The marine food is rich in iodine but unfortunately people make less use of marine foods perhaps because of their low income status and high price of the food. The problem of iodine deficiency and loss from whatsoever food and water is used is further coupled by the unsuitable and unhealthy cooking methods and other lifestyles.

CONCLUSION

In all the altitudinal zones, the iodine content in the soil (0.970 to 1.230 mg kg^{-1}) and fresh (drinking) water (1.6-4.2 µg L^{-1}) sample sites is less than the world level averages in soils (2.8 mg kg^{-1}) and drinking water (8.7 µg L^{-1}) sources. The iodine content in soils showed a close association with OM and pH. Iodine in soils has direct relationship with OM and inverse relationship with pH. Iodine content in water samples showed a relationship with iodine content in surrounding soils. Leaching and run-off play an important role in the transfer of iodine from surroundings soils to water bodies. About 17.6% people surveyed suffer from thyroid disorders. There is decrease in the prevalence of IDDs from LFHs to UFHs and from LFHs-1 to UFHs-2 because of the lifestyle of people. At sample village level, there is also a decrease in the percentage prevalence of IDDs with altitude in respective soil types except SS5-ANG of UFH region. This is due to high (4.90%) OM in soil at SS5-ANG and dependence on vegetarian food.

RECOMMENDATION

Certain simple and low cost suggestions to minimize the magnitude of IDD sufferers in the area under study are needed for the area is rural in character. The people of the area should make 100% use of iodized salt by the whole population. Special care should be taken of pregnant and nursing mothers after consulting a registered medical practitioner. They should avoid long period boiling, braising, blanching and frying of foods to avoid the loss of nutrients especially iodine. Iodine should be added to drinking water and the irrigational water through fertigation to increase the content of iodine in the natural systems of soil and water. More and more sea foods, eggs, dairy products, watercresses, iodized salt, grains and fruits should be used. The people should also avoid drinking of boiled water in coliform risk free areas.

Conflict of interest

Authors have none to declare.

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