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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.

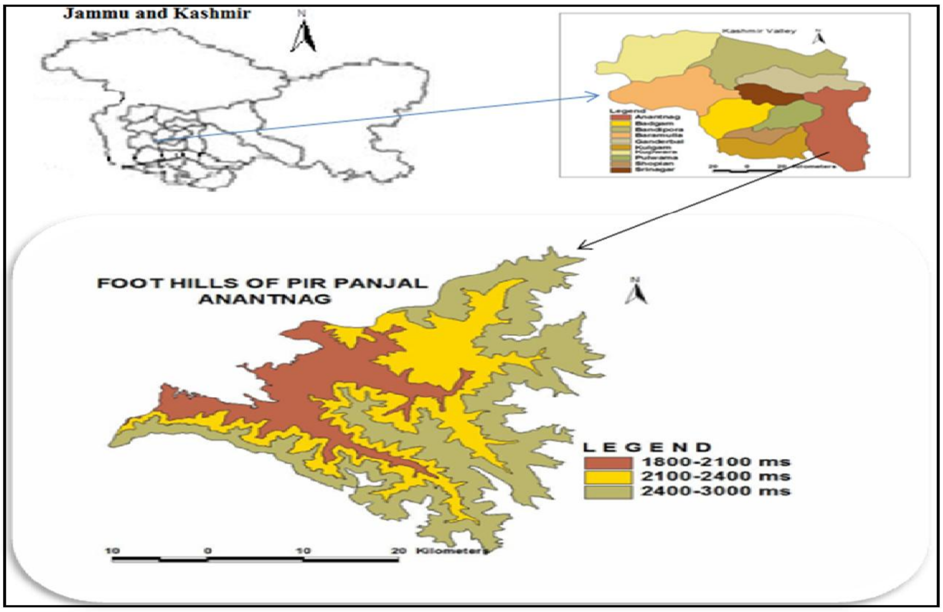

Figure 1. Location map of Foot Hills of Pir Panjal range in Anantnag (Generated from SOI toposheets, 1971)

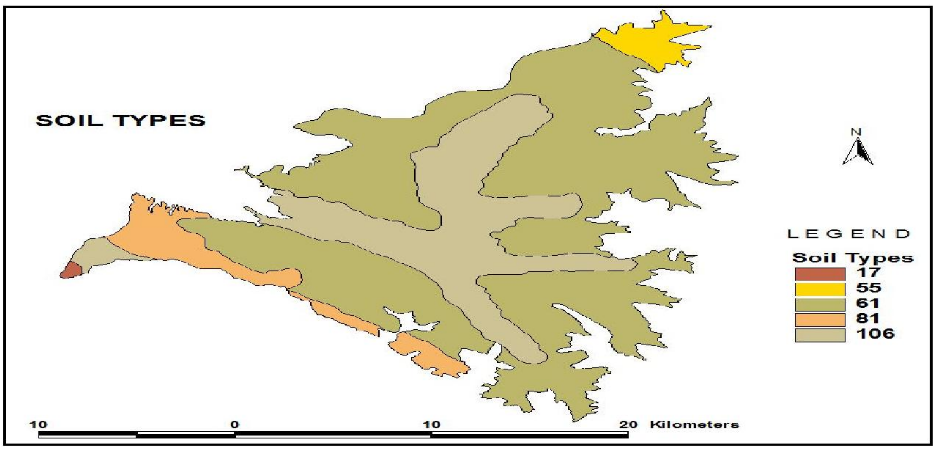

Figure 2. Soil map of the study area (Generated from Soil Map of J & K, ICAR, Nagpur-2010)

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.

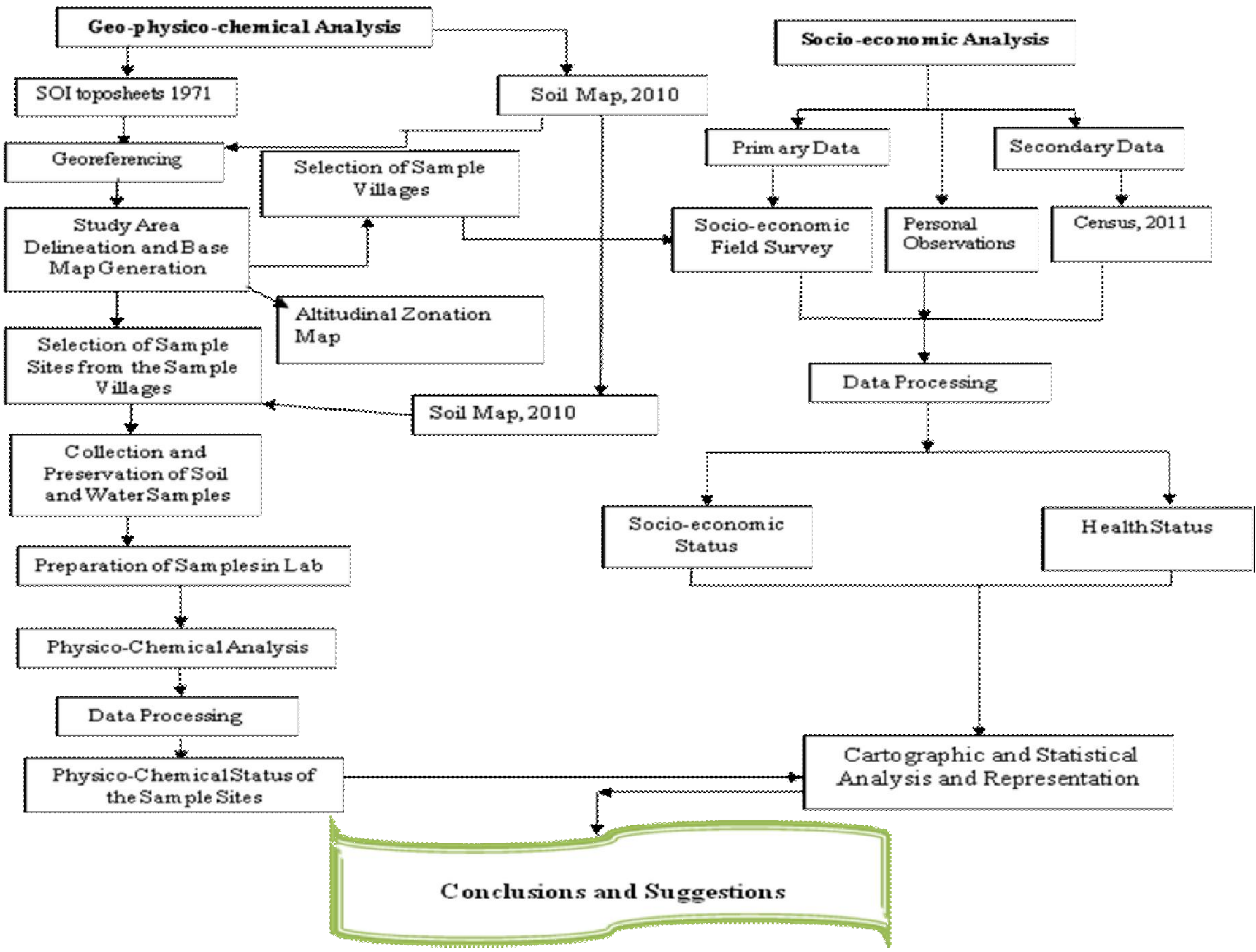

Figure 3. Flow Chart of Methodology

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

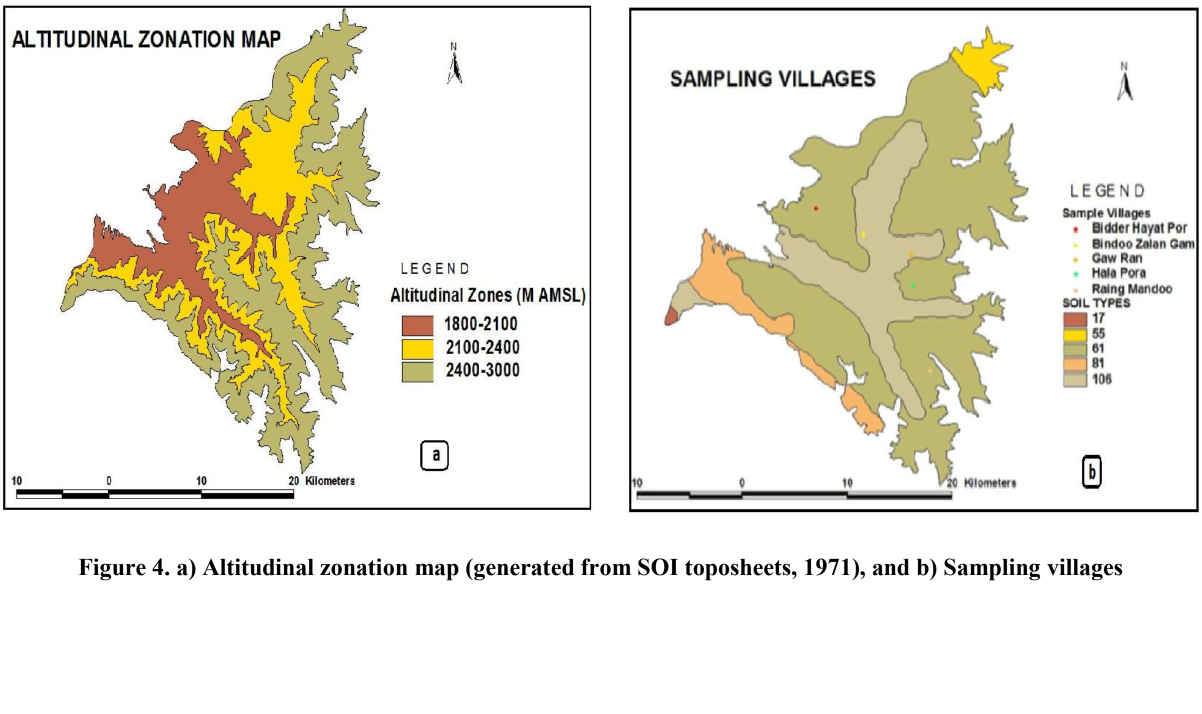

Figure 4. a) Altitudinal zonation map (generated from SOI toposheets, 1971), and b) Sampling villages

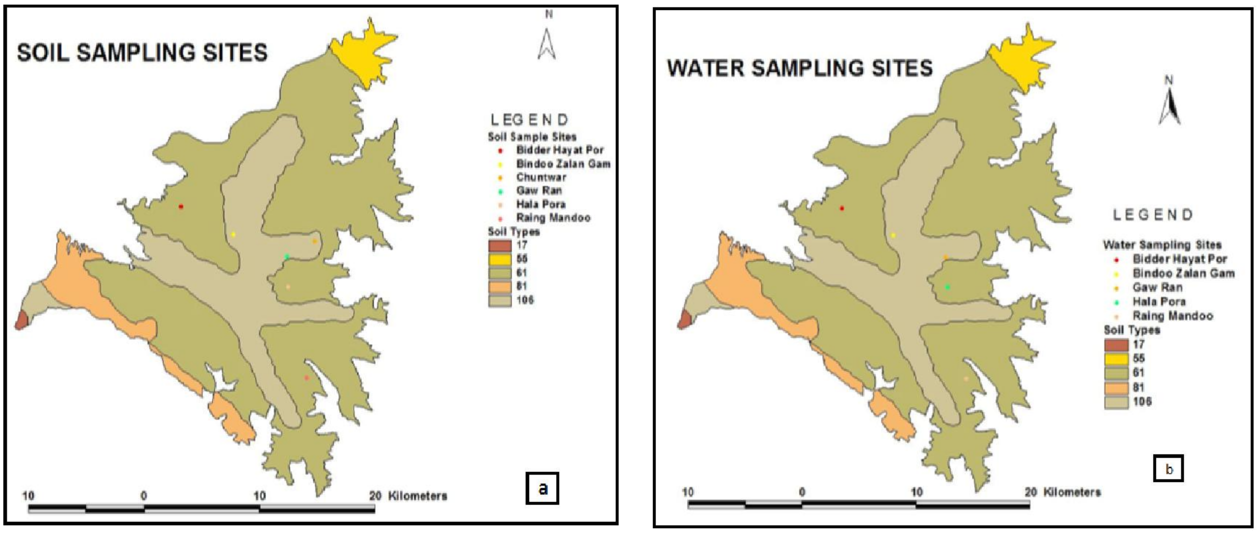

Figure 5. a) Soil Sampling Sites, and b) Drinking Water Sampling Sites

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

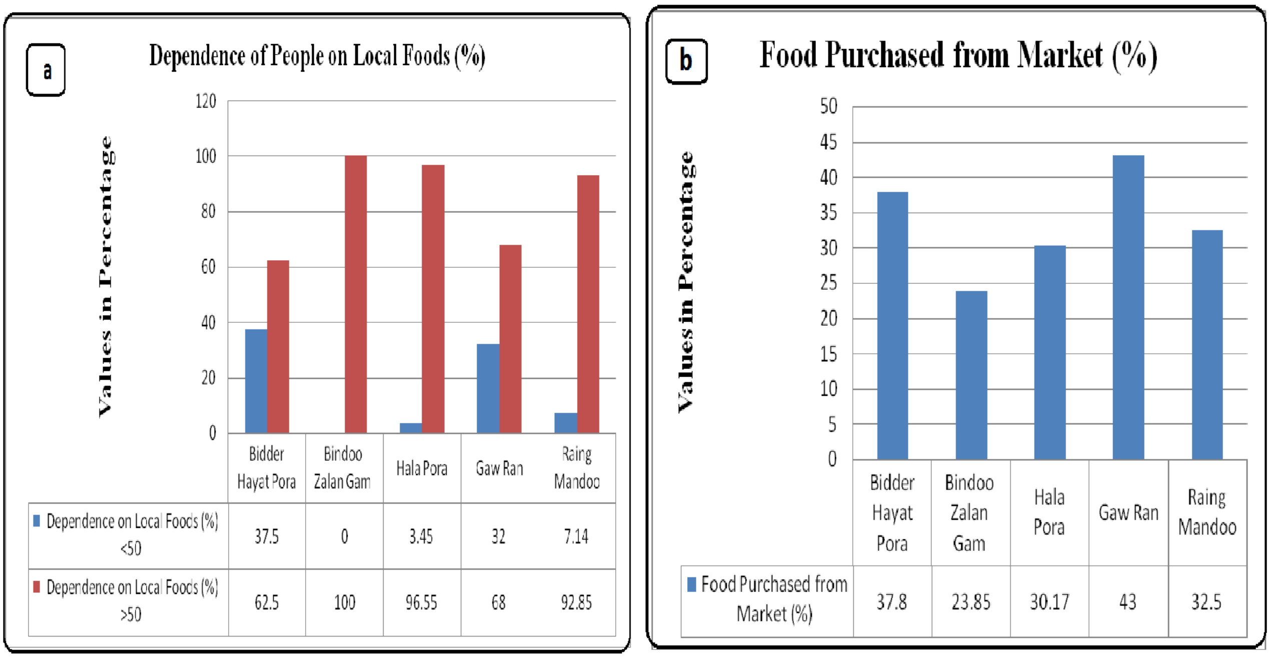

Figure 6. a) Dependence on Local foods (%) and b) Food purchased from Market (%)
(Data collected through field survey by the authors, 2013)

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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