ISSN 2229-5518

Evaluation of Groundwater Quality and its Suitability for Drinking Purposes – A Case of Leh Town, Ladakh (J&K), India

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Abstract: The present study, describes about the water dynamics in fast changing town of Leh, located in the state of Jammu and Kashmir, India. Groundwater since ancient times in the form of springs provided ample water for the region and its contribution has increased manifold in the wake of recent spurt in bore well installations, especially, in Leh town. Due to increasing urbanization, with surge in a huge floating population in the absence of a sewerage link in summer tourism boom season, puts an extra stress on the limited water resources of the area and with the rising living standards, grey and black water is being disposed off in soak pits or septic tanks without any treatment. This may lead to pollution of groundwater resources especially, in the densely populated residential areas. For insuring sustainable development of groundwater, in the absence of any observation wells for constant monitoring of quality or quantity of groundwater and the unregulated installation of bore-wells makes this quality characterization very significant and helps in future management. The physico-chemical parameters like pH, electrical conductivity, turbidity, total dissolved solids, hardness, alkalinity, nitrates, fluoride, chlorides were analyzed to meet the objective of the study. The results revealed that in general, the present status of groundwater quality is suitable for drinking purposes and out of 20 total samples evaluated, 75% of samples had NTU (Nephelometric Turbidity Unit) above desirable limit while 10 % samples each recorded TDS (Total Dissolved Solids) and EC (Electrical Conductivity) above desirable limits.

Key Words: Drinking Water, Cold Desert, Sustainable Development, Turbidity, Sewerage

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1 INTRODUCTION

Groundwater quality is of outmost concern in the case of Leh town as the town is facing rapid urbanization, propelled by the tourism boom, in recent years. The town's water supply network is dependent wholly-solely on groundwater supplied by the extensive spring network in the region. Along with the region's (Public Health Engineering Department) PHE which supplies water to the town's 21 wards from groundwater sources through pipelines and (Public Stand Posts) PSPs in summers and in winters by water tankers as the pipes freezes and explodes during winters. There is a wide presence of private bore wells in the town and adjoining areas through which the residents fulfill their water requirements. The water quotient is very important in this town as it lies in a cold desert and if we see the whole surrounding areas, we can definitely say this town is an oasis in a desert as it is surrounded by icy cold mountain ranges of the Himalayas which are one of the highest in the world. Water since time immemorial has played an important role in the historical development of this area as popular culture revolves around water conservation aspects. Whether it is traditional irrigation system, sanitation system or folkways and mores, judicious use of water is at the heart of this town's history and culture. Since due to increase in construction rate particularly from the tourism boom stress on existing groundwater resource is more current times and needs more emphasis now. As in case of Sholapur city, groundwater quality deterioration is not due to urbanization but due to general apathy of the public towards this valuable resource (Naik et al., 2008).

Also as per water quality analysis in the Sorang Hydroelectric power project area in Kinnaur, India the main source of water pollution was domestic (Renu et al., 2014). Thus more detailed study needs to be carried on regarding this resource in Leh town for better water management policy implementation.

2 DESCRIPTION OF THE STUDY AREA

Ladakh region which is part of the northernmost Indian state, Jammu and Kashmir comprises of two districts Leh and Kargil. Topographically the whole district is mountainous with parallel ranges of the Himalayas, mainly Zanskar, Ladakh and the Karakoram ranges. The Shayok, Indus and Zanskar rivers flow between these ranges and most of the population is inhabited in these valleys. The elevation of Ladakh Region ranges from 2300 m to 5000 m above mean sea level (amsl). District Leh with an area of 45100 km^2 is the 2^{nd} largest district in India after Kutch in Gujrat with an area of 45652 km^2. As Ladakh is a cold desert, precipitation averages around 61mm/annum and occurs in the form of snow and rain both in winter and summer months respectively (Raksha et al.,2013). Ladakh is a semi-autonomous region of India, governed by the Ladakh Autonomous Hill Development Council of Leh and Kargil simultaneously for Leh and Kargil District. The district is divided into 9 Community Development Blocks namely Leh, Khaltsi, Nyoma, Durbuk, Kharu, Nubra, Saspol, Panamic and Chuchot which is further divided into 03 tehsil namely Leh, Sumoor and Khaltsi. Leh is the district headquarter and the only township in the district.

2.1 Leh Town

It is located in district Leh between North latitude 34°13’00” to 34°8’00” and East longitude 77°38’00” to 77°32’00” (Fig.1.). Leh is about 434 kilometers from Srinagar (National Highway) NH 1D and 474 kilometers from Manali (NH 21). The town is divided into 21 administrative wards and the relief ranges from highest 4500m (amsl) to lowest 3250m (amsl). The town is classified as Class III (Urban Agglomeration) UA and has a (Notified Area Council) NAC. The population as per 2011 census is 30,870 which has risen from 28,639 (2001) census thus recording a growth rate of 7.8%. The region caters to a huge population of army personnel deployed here but the majority is based outside the town, with an ever surging tourist population. The tourism industry and army presence is the pull factor for a large floating population of migrant labourers particularly in the short summer seasons from June to September.

2.2 Historical Background

Leh town dates back to the 17^{th} century when this became the capital of Ladakh region replacing Shey, located 15 km away from Leh city centre by the great king Singhe Namgyal. Ladakh being an important stopover in the Trans Himalayan trade especially the pashm trade so was invaded by the Dogra rulers and the Britishers in order to control the Silk route connecting with Central Asia (Kimura, 2013).

2.3 Geology and Hydrogeology

The geology and hydrogeology of a particular area determines the groundwater flow and its properties. Rocks of the district are constituted by igneous, metamorphic and sedimentary rocks that are sandwiched between tertiary granitoid batholiths of Ladakh and Karakoram ranges. Leh town shows terraces and valleys show a plethora, both erosional (amphitheaters) and depositional land forms, belonging to glacial (moraines), fluvio-glacial (glacial out wash), mass wasting (alluvial fans). Terraces forms the high ground between the hill ranges and the valleys, sloping Southward and are composed of boulders and cobbles of moraine sediments with sand, silt, clay and

ISSN 2229-5518

gravel of fluvio glacial origin, derived from Ladakh range. The movement of groundwater is affected by the unconsolidated formations like alluvium, scree and talus formations (CGWB.,2009).

The upper part of this valley is laden with well preserved repository of lateral and terminal moraines also the glaciers melt/rain water drains the lower reaches, gently sloping valley southwards. The valley fill deposits are mainly boulders and gravel mixed with salt and sand material. Groundwater occurs as unconfined condition in this formation and aquifers in this region are made of boulders and clastic material in clay, silt, matrix of sand, silt and clay.

With the rising stress from tourism sector many shallow groundwater may be prone to contamination till the time the sewerage project is successfully completed. Till the developmental phase, raw sewage continues to be discharged under the ground the soak pits which are moreover a cesspool without any particular design. Already in Chubi area of Leh town, bacterial contamination was found in 2014 and as drinking water source was tapped from the Gyalung spring high up near the Gangles village through a underground pipeline supply so, it was very ironic to see that a spring rich area like Chubi is drinking water of the Gyalung spring as they have contaminated their own source and using that handpump for washing purposes only (Dolma et al., 2015).

3 MATERIALS AND METHODS

A reconnaissance survey was carried out initially in order to get a clear picture of the present scenario and the environmental changes undergoing in the area, for pinpointing the problems. For primary data, a total of 20 groundwater samples were collected from different locations in Leh town which spans an area of 1893 hectares/18.93 km^2 and is divided into 21 administrative wards (Gondhalker et al., 2013). The samples were collected in the month of May (Pre monsoon) and October (post monsoon), 2013 (Fig.2.). Prior to sample collection, all the plastic bottles were thoroughly washed and sun-dried and before sample collection the plastic bottles were rinsed twice with the water sample to be collected. The bottles were then labeled and the co-ordinates of the sampling sites were duly noted. Parameters like Temperature, pH, and EC were analyzed on the spot using potable water and soil analysis kit. For the analysis of other parameters, the bottles were taken to the laboratory and stored at 4^oC and further analysis completed as per standard procedures (Table. 2.). Water samples were analyzed in the geochemical laboratory of the Department of Geology and Water Resources Department, Chandigarh according to the standard methodology given by American Public Health Association (2012), Trivedy and Goel (1986) and Central Pollution Control Board, New Delhi (2001). For map making survey of India toposheet no. 52F/12 was used for digitization in the (Global Information System) GIS software, ArcGIS and Global Positioning System (GPS) device was used for identifying sampling location. Also an online growth rate calculator (Endmemo) was used for prediction of growth rate (2001-2011).

Secondary data was also collected from various government and non government institutes from their websites and related portals. For the secondary scientific data collection institutions like PHE (Public Health Engineering Department), LEDeG (Ladakh Ecological Development Group) and (FRL) Field Research Laboratory of the DRDO (Defence Research and Development Organization) of India were visited. A wide variety of print and visual materials were consulted along with open ended questionnaire session regarding historical

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description of the area from various scholars, authors and department people of Ladakh Cultural Academy.

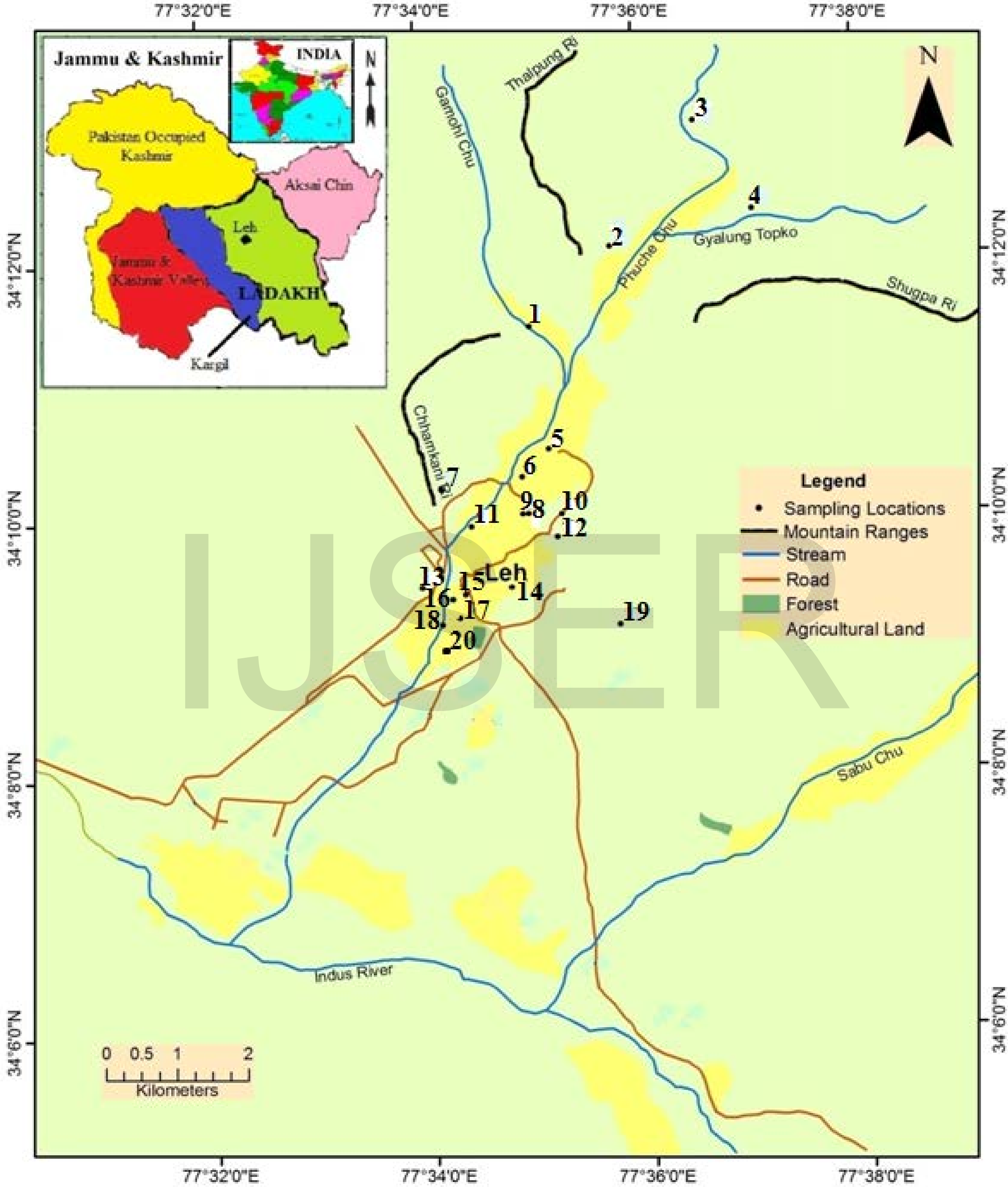

Fig.1. Location Map of Water Sampling Stations in the Study Area

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4 RESULTS AND DISCUSSIONS

Physico-chemical analysis of water samples collected from different groundwater locations around Leh town was analyzed and the distribution of water samples showing various parameters against maximum permissible and desirable limits are shown in Table 1.

Table 1. Desirable and Permissible Limits in Groundwater Samples

S. No.	Parameter	Max. permissible limit for drinking water	Desirable limit for drinking water	No.of water samples analyzed	No. of Samples above		Range		Mean Value	Std Deviation
					*DL	*PL	Min	Max		
1.	pH	No relaxation	6.5-8.5	20	Nil	Nil	7	8	7.55	0.34
2.	EC	0-2000 µS/cm	750 µS/cm	20	2	Nil	205	849	441.51	188.87
3.	TDS	2000 mg/l	500 mg/l	20	2	Nil	134	565	291.22	125.31
4.	TH	600mg/l	300mg/l	20	Nil	Nil	90	188	135	30.29
5.	Cl^-	1000 mg/l	250mg/l	20	Nil	Nil	2.13	4.97	3.51	0.99
6.	Ca^{2+}	200 mg/l	75 mg/l	20	Nil	Nil	11.77	45.11	32.15	8.00
7.	Mg^{2+}	100 mg/l	30 mg/l	20	Nil	Nil	2.92	26.35	14.04	8.22
8.	NO_3^{2-}	No relaxation	45mg/l	20	Nil	Nil	0	1.00	0.16	0.26
9.	Na^+	-	-	20	-	-	0.1	31.9	7.54	8.35
10.	K^+	-	-	20	-	-	0.8	3.2	1.6	0.62
11.	SO_4^{2-}	400 mg/l	200 mg/l	20	Nil	Nil	9.39	13.70	10.69	1.53
12.	PO_4^{2-}	0.1mg/l	-	20	Nil	Nil	0	0.47	0.06	0.10

*DL- Desirable Limit
*PL- Permissible Limit

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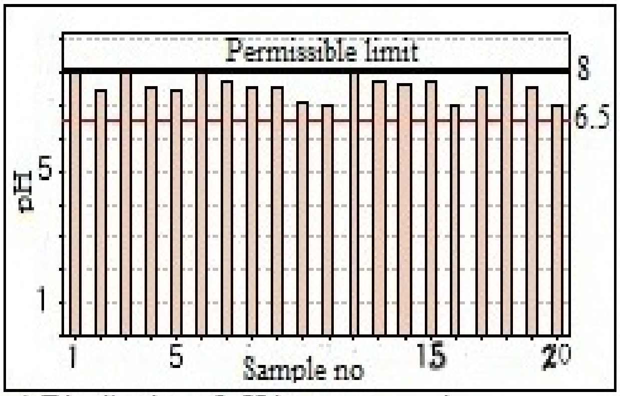
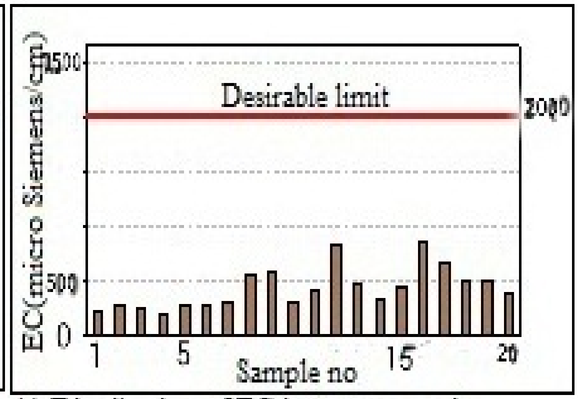
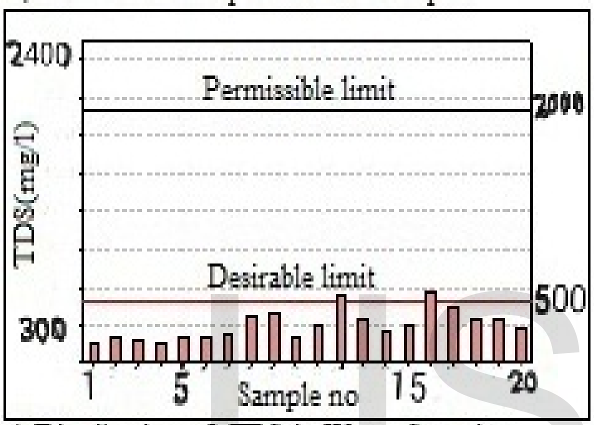


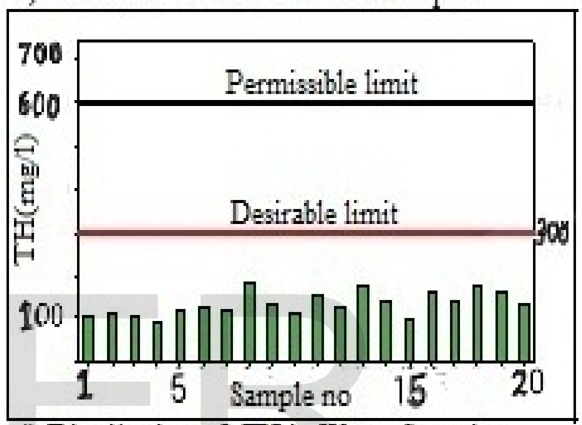
a) Distribution of pH in water samples



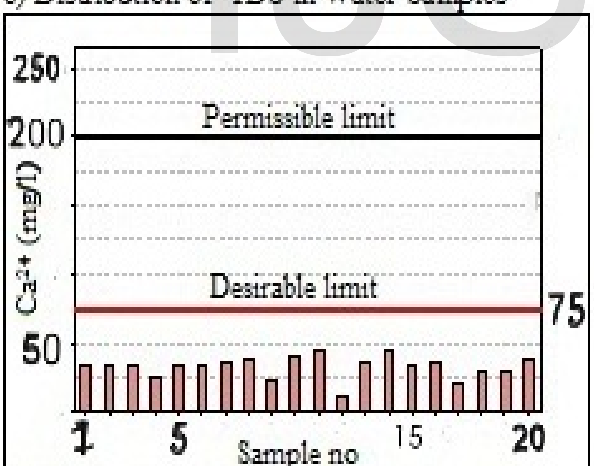
b) Distribution of EC in water samples



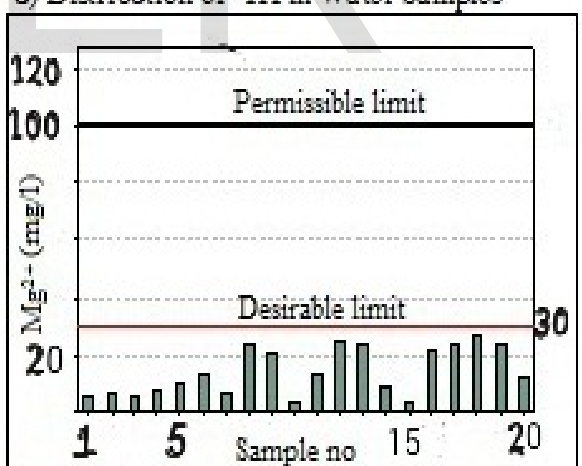
c) Distribution of TDS in Water Samples



d) Distribution of TH in Water Samples



e) Distribution of Ca^{2+} in Water Samples



f) Distribution of Mg^{2+} in Water Samples

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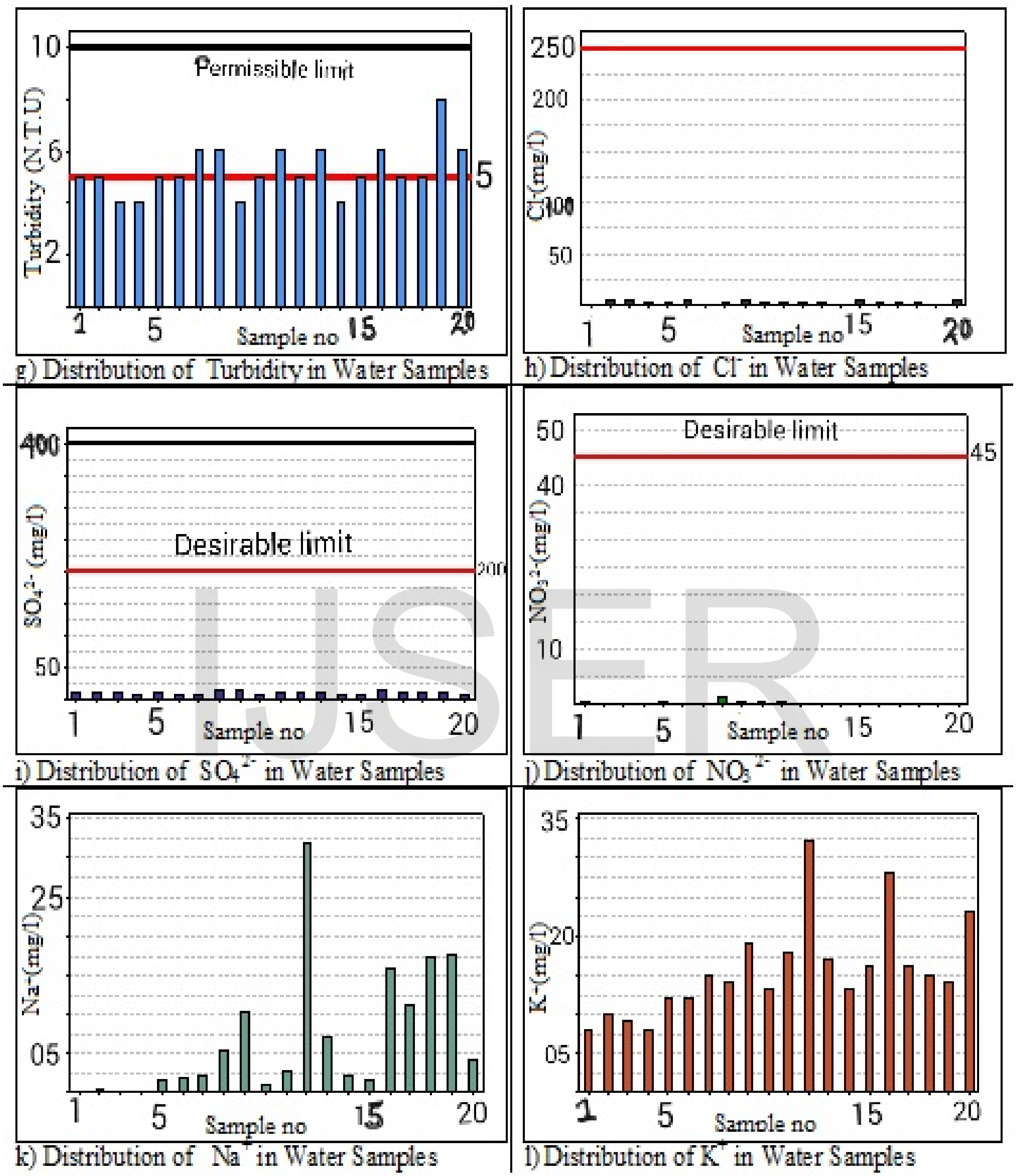

Fig. 2. Distribution of Various Parameters Water Samples in the Study Area

4.1 pH and Electrical Conductivity (EC)

The pH (hydrogen ion concentration) of water is very important indicator of its quality as it depends on the presence of phosphates, silicates, borates, fluorides and some other salts in dissociated form (Prasad and Ayer, 1983). In general waters having pH between 6.5 and 8.5 are categorized as suitable, whereas waters with pH 7.0 to 8.0 are highly suitable for all purposes.

The pH value of the surface water of the study area during pre monsoon varies from 7 to 8 with mean value of 7.55 and varied from 7.00 to 7.9 with mean value of 7.24 during post monsoon which indicated that water is slightly alkaline in nature but suitable for domestic purposes (Herojeet *et al*, 2013). Electrical conductivity of water is also an important parameter for determining the water quality. It is a measurement of water's capacity for carrying electrical current and is directly related to the concentration of ionized substance in the water. In the present study, EC values of surface water ranged between 205 µmhos/cm to 849 µmhos/cm with mean value of 441.59 µmhos/cm in pre monsoon and between 201 µmhos/cm to 826 µmhos/cm with mean value of 404.54 µmhos/cm during post monsoon. Distribution of pH and EC in samples is shown in Fig. 2. (a &b)

4.2 Total Dissolved Solids (TDS)

Total dissolved salt concentrations is the primary indicator of the total mineral content in water and are related to problems such as excessive hardness. Total dissolved solids in the water samples of the study area varied from 134 mg/l to 565 mg/l with mean value of 291.22 mg/l during pre monsoon. During post monsoon, the value of TDS varied from 130 mg/l to 561 mg/l with mean value of 279.22 mg/l. The distribution of TDS in the groundwater samples of the study area is depicted in Fig.2. (c).

4.3 Total Hardness (TH)

It results from the presence of divalent metallic cations of which calcium and magnesium are the most abundant. The concentration of total hardness in the water of the study area varied from 90 mg/l to 188 mg/l with mean value of 135 mg/l during pre monsoon and from 72 mg/l to 172 mg/l with mean value of 120.63 mg/l during post monsoon. Fig.2. (d) shows the distribution of TH in the groundwater samples of the study area.

4.4 Calcium (Ca^{2+}) and Magnesium (Mg^{2+})

The amount of calcium in the groundwater of the study area varied from 11.77 mg/l to 45.41 mg/l with mean value of 32.15 mg/l during pre monsoon and between 10.09 mg/l to 40.37 mg/l with mean value of 27.29 mg/l during post monsoon. Magnesium concentration in the surface water is generally less than calcium due to the slow dissolution of magnesium bearing minerals and greater abundance of calcium in earth crust. Magnesium concentration in the groundwater of the study area ranged between 2.92 to 26.35 mg/l with mean value of 14.04 mg/l during pre monsoon and between 3.41 mg/l to 24.88 mg/l with mean value of 13.66 mg/l during post monsoon. Fig.2. (e & f) indicates that the water of the study area were well within the permissible limits of calcium and magnesium thus, it is safe for drinking purposes.

present. The chloride ion in the surface water of the study area in pre monsoon season varied between 2.13 mg/l to 4.91 mg/l with mean value of 3.51 mg/l. In post monsoon season, it varied between 1.42 mg/l to 6.39 mg/l with mean value of 2.90 mg/l. Fig. 2. (h) Clearly indicates that all the water samples of the study area were within the desirable limit and hence fit for consumption. Fluoride (F) is essential in trace amounts for all human beings and is one of the normal constituents of all diets. The desirable limit of fluoride in drinking water is 1 mg/l (BIS, 1991), Mckee and Wolf (1963). Fluoride concentrations in all the groundwater samples were found to be within the permissible limit of 1.5 mg/l Fig. 2. (i). In pre monsoon season the fluoride concentration of groundwater varied between 0.02 mg/l to 1.30 mg/l with mean value of 0.59 mg/l. In post monsoon season the concentration of fluoride varied between 0.04 mg/l to 1.30 mg/l with mean value of

4.5 Turbidity

Turbidity refers to how clear the water is. It is a measure of the degree to which water loses its transparency due to the presence of suspended particulates. The more total suspended solids in the water, the murkier it seems and the higher the turbidity. It is considered as a good measure of the quality of water. Turbidity in the water samples of the study area varied from 3 NTU to 8 NTU with mean value of 5.8 NTU during pre monsoon. During post monsoon, the value of turbidity varied from 5 NTU to 8 NTU with mean value of 5.93 NTU. All the samples analyzed were within desirable limit of 5 NTU (BIS, 1991) and are fit for human consumption. The distribution of turbidity at different sampling locations is shown in Figure 2. (g).

4.6 Chloride (Cl $^-$) and Fluoride (F$^-$)

Chloride in drinking water is not generally harmful to human beings until high concentration is present. The chloride ion in the groundwater of the study area in pre monsoon season varied between 2.13 mg/l to 4.91 mg/l with mean value of 3.51 mg/l. In post monsoon season, it varied between 1.42 mg/l to 6.39 mg/l with mean value of 2.90 mg/l. Fig. 2. (h) Clearly indicates that all the water samples of the study area were within the desirable limit and hence fit for consumption. Fluoride (F) is essential in trace amounts for all human beings and is one of the normal constituents of all diets. The desirable limit of fluoride in drinking water is 1 mg/l (BIS, 1991), Mckee and Wolf (1963). Fluoride concentrations in all the water samples were found to be within the permissible limit of 1.5 mg/l Fig. 2. (i). In pre monsoon season the fluoride concentration of surface water varied between 0.02 mg/l to 1.30 mg/l with mean value of 0.59 mg/l. In post monsoon season

0.62 mg/l. Only three samples crossed the desirable limit of 1.0 mg/l.

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4.7 Nitrates (NO_3^{2-})

Excess of nitrates consumed by humans particularly infants is likely to cause health hazards and may lead to Methaemoglobinemia (Blue baby) disease. Distribution of nitrate in groundwater samples are shown in Fig. 2. (j). The nitrate content of water samples in the study area was varied from 0 mg/l to 1.00 mg/l with mean value of 0.16 mg/l during pre monsoon and between 0 mg/l to 0.97 mg/l with mean value of 0.16 during post monsoon.

4.8 Sodium (Na^+) and Potassium (K^+)

Sodium is the most abundant element of the alkali-earth group in the earth crust with average value 2.5%. In igneous rock, sodium is slightly more abundant than potassium, but in sediment, sodium is less abundant. BIS (1991) & WHO (2006) have not given any guideline limit for sodium and potassium in drinking water. Sodium concentration ranged between 0.1 mg/l to 31.9 mg/l with mean value 7.54 mg/l during pre monsoon. During post monsoon, the sodium content varies from 0.07 mg/l to 27.8 mg/l with mean value 6.56 mg/l.

Potassium is an essential element for both plants and animals but very high potassium concentration may be harmful to human nervous and digestive system. Potassium concentration ranged between 0.8 mg/l to 3.2 mg/l with mean value 1.6 mg/l during pre monsoon and between 0.6 to 2.7 mg/l with mean value 1.26 mg/l during post monsoon. The concentration of potassium in the study area is very low. It is not feasible to assess the suitability of water for drinking

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purpose as no agency have given any standard with respect to potassium.

Table 2. Methods/Procedures used for sample analysis

Parameter	Methods/ Procedures	Percentage of Samples above	
		*DL %	*PL%
EC	Electrical Conductivity meter	10	Nil
TDS	TDS Meter	10	Nil
Turbidity	Nephelometer	75	Nil
pH	pH meter	Nil	Nil
Ca^{2+}	EDTA-Titrimetric method	Nil	Nil
Mg^{2+}	By Difference	Nil	Nil
Na^{+}	Flame photometric method	Nil	-
K^{+}	Flame photometric method	-	-
Cl^{-}	Argenoto metric method	Nil	Nil
F^{-}	SPADNS method	Nil	Nil
SO_4^{2-}	Turbidity Method	Nil	Nil
NO_3^{2-}	Ultraviolet Spectrophotometer method	Nil	Nil

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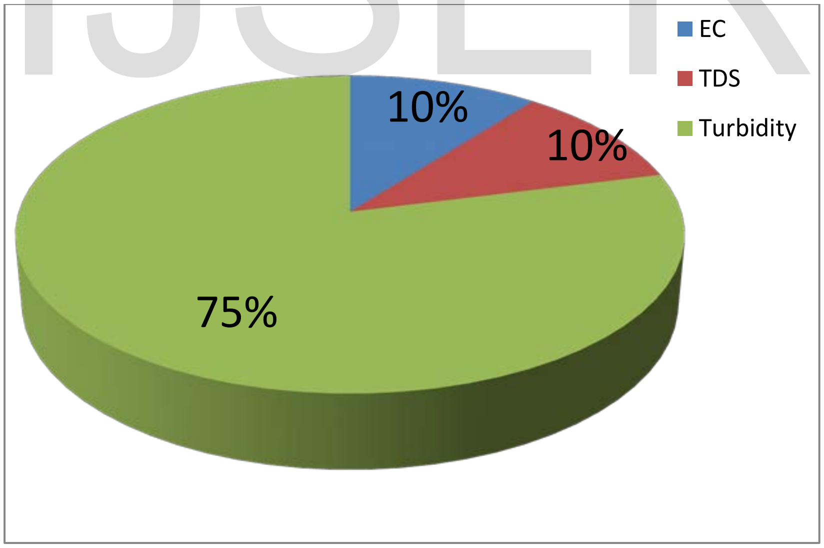

Fig. 3. parameters above BIS Desirable Limit

4.9 Hydrochemical Facies of Surface Water

The hydrochemical facies of a particular place are influenced by geology of the area and distribution of facies by the hydro-geological controls. In the present study, the water samples of the study area has been classified as per Chadha's diagram (Chadha, 1999) (Table. 3.). The diagram is a modified version of Piper trilinear diagram (Piper,

ISSN 2229-5518

1944) and the expanded Durov diagram (Durov, 1948).

The chemical analyses data of all the water samples collected from the study area have been plotted on Chadha's diagram (Fig. 4.) and results have been summarized in Table 2. while the percent pie chart is given (Fig. 3.). It is evident from the results that the water samples collected from the study area fall in Group 1 (Ca^{2+}- Mg^{2+}-Na^{+}- K^{+}), Group 5 (Ca^{2+}-Mg^{2+}- HCO_3^-) and Group 6 (Ca^{2+}-Mg^{2+}- Cl^--SO_4^{2-}) type. However majority of the surface water sample fall in Group 5 (Ca^{2+}-Mg^{2+}- HCO_3^-) which means alkaline earths and weak acidic anions exceed both alkali metals and strong acidic anions, respectively. Such waters have temporary hardness.

Table 3. Summarized Results of Chadha's Classification

Classification/ Type	Surface water
Group 1 (Ca^{2+}- Mg^{2+}-Na^{+}- K^{+})	5
Group 2 (Na^{+}- K^{+}- Ca^{2+}- Mg^{2+})	--------
Group 3 (HCO_3^-- Cl^--SO_4^{2-})	---------
Group 4 (SO_4^{2--} - HCO_3^--Cl^-)	---------
Group 5 (Ca^{2+}- Mg^{2+}- HCO^-)	10
Group 6 (Ca^{2+}- Mg^{2+}- Cl^--SO_4^{2-})	5
Group 7 (Na^{+}- K^{+}- Cl^--SO_4^{2-})	----------
Group 8 (Na^{+}- K^{+}- HCO^-)	----------

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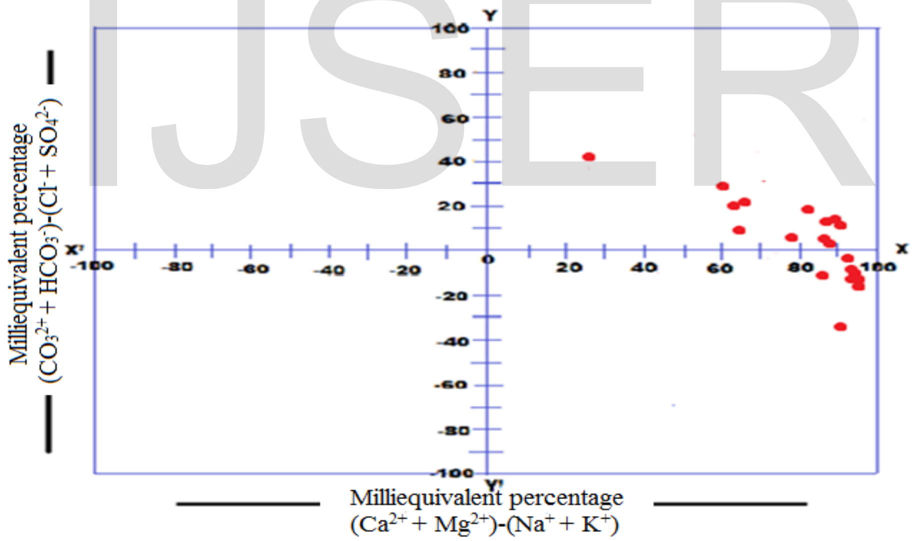


Fig. 4. Chadha's Diagram for Groundwater Samples

4.10 Groundwater Supply

The Public Health Engineering Division supplies bulk of its water through groundwater and is equipped with Percussion rigs P-5000 and Aqua drills R-50 (Air rotary rig). In addition to it manual hand pumps are installed as well due to the closing of schemes during winter freezing period. The elaboration of schemes in operation/progress of Leh town is mentioned hereunder:

Gyalung water supply scheme: It is located at about 5 km on Leh-Nubra road the spring at Gaylung has been tackled to supply 1.25 lac gallons per day. This spring remains operational throughout season and caters half of the town's water requirements.

T-Trench water supply scheme: This scheme is located at about 3 km near Gompa village on Leh-Gangles road, supplies 0.40 lac gallons per day and also operational during winters.

Juma-Bagh water supply scheme: This is the pioneer water supply scheme of Leh Town which is totally spring fed and is located within the town supplying 0.25 lac gallons per day functioning throughout the season.

Skalzangling borewell scheme: This tubewell is located at Skalzangling 2 km from leh bazaar on airport road supplying 0.40 lac gallons of water which is further put into town's distribution network.

Skara spring water supply scheme: This scheme feeds lower part of Leh through 11 Public Stand Posts (PSP) throughout 24 hours. Along with it this spring caters to the demand of nearby defence establishment.

Tanker town service: On daily basis the divisional tankers delivers 0.43 lac gallons of water to town population not covered by PSPs.

At present 40 lpcd are being supplied which the PHE Department is planning is increase to 135 lpcd by year 2018 that is after the completion of the ongoing Drinking Water and Sewerage project in Leh Town. This totals to 12.3 lac litres daily as per the population of town which is 30870 as per 2011 census.

4.11 Future Growth and Water Demand

According to the Malthusian population growth formula when the value of r that is growth rate is unknown we predict the population after 20 years which is in 2031 with the known population of Leh town in 2001(28639) and 2011(30870) census data. So the population is estimated at 35873 in 2031, thus the lpcd demand of water at 40 lpcd will increase to 14.3 lakh litres from 12.3 lakh litres in 2011. Exponential growth formula: $P(t)=P_o e^{rt}$.

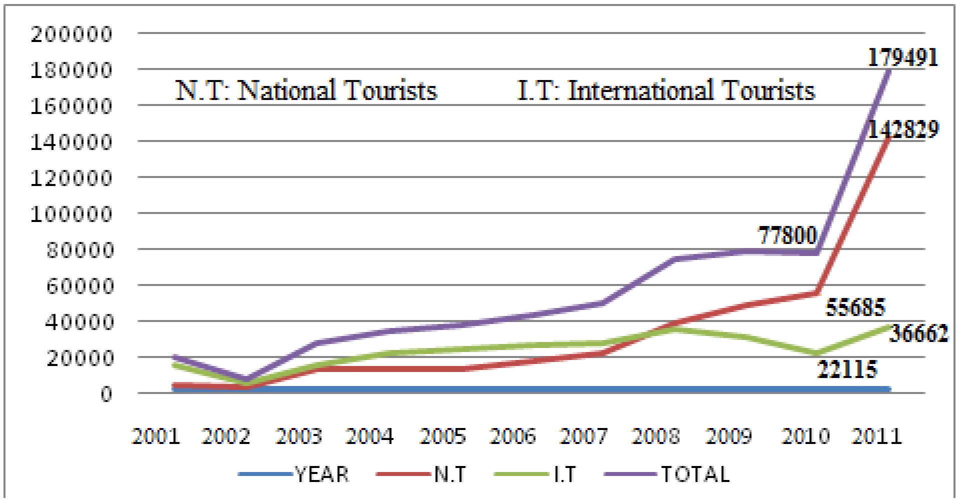
Where P(t):Final population after time t; P_o:Initial population at time t=0; r=growth rate; t=time. The growth rate comes to +0.75% for the time period 2001-2011 which is quite a significant factor and future town planning should assimilate this factor for a robust and sustainable town in coming times.

4.12 Tourism and the water nexus

Ladakh have come a long way from 527 tourists, since 1974 to more than the population of district of 1,79,491 in 2011. While the tourists arrival for last decade for the period (2001-2011) shown in (Fig.5) shows a steep increase in total tourist arrivals. Further the district hosts an increasing tourist population especially during the summer months and the success of bollywood film '3 idiots' has immense contribution in increasing the national tourists influx, in comparison to international numbers. Film induced tourism is boosted by the success of a movie based or set in a particular region as it offers an opportunity to relive or experience, see and learn novelities through entertainment and pleasure (Gjorgievski and Trpkova, 2011).

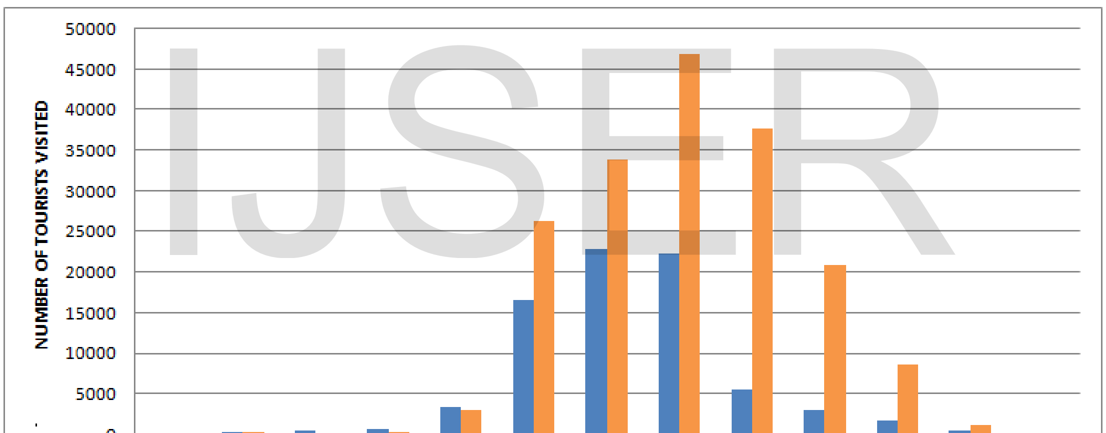
A month wise breakdown of tourist influx in 2010 and 2011 (Fig.6.) shows the most favourable months are in June to August.

ISSN 2229-5518



(Source: Statistical Handbook, 2010-11)

Fig 5: Tourist Arrivals in Leh District from (2001-2011)



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	MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Series1	2010	381	437	606	3410	16518	22889	22415	5575	3041	1802	581	145
Series2	2011	313	120	337	3001	26310	33908	46843	37756	20833	8621	1255	194

(Source: Statistical Handbook, 2010-11)

Fig. 6. Monthly Tourists Visit (2010-2011)

The number of tourists in month of june 2010, 2011 and 2012 (Table. 4.) and getting the daily average numbers by dividing it by 30 and finally deriving the per day water requirement for month of june by multiplying it by 40 lpcd. In order to prevent degradation of water source and to augment the existing water supply volume in Leh town, work began on ‘Drinking water and Sewerage project’ in 2013 and time frame for the project completion is 3 years till 2016 (Bhalkang, 2014). This project aims to increase 135 lpcd from the existing 40 lpcd supplied by the Public Health Engineering Department (PHE), Leh.

Table 4. Daily Water Requirement by Tourists in June Month

Year	2010	2011	2012
Tourists Visited in Month of June	44241	63989	56801
Average Daily Visit by Dividing 30	1475	2133	1893
Minimum Daily Water Required in (Litres Per Capita Daily)	40	40	40
Total Water Required Daily in Lac Litres Daily	59000	85320	75720

Now, if we add the water requirement daily in the peak tourist month of june in 2011 (85320) and daily requirement by the local population (12.3 lacs), total estimate comes to about 13.2 lacs eventually showing 6.9% increase in daily water requirement for june month.

5 CONCLUSION

The complete and systemic study of water quality and quantity in the study area revealed that apart from domestic sources, there were no other major sources of pollution observed in the project area. Turbidity of 75% of samples was above desirable limit and the majority of samples which recorded a high level of NTU could be attributed to the loose friable and weak sandy loamy soil. Terraces form the main topography of the valley area. The unconsolidated formations like alluvium, scree and talus formations present along the terrace plays a vital role in the recharge of ground water. These fluvo glacial structures bring clastic materials in clay, silt and sand matrix along with glacial melt water in the aquifer system and are responsible for the flow of groundwater. Also 10 % of the samples were having EC and TDS above desirable limit but they were well within permissible limit. While the quantity aspect highlights the acute stress of tourism industry on the available groundwater resources. Thus, it is concluded that the groundwater quality in the study area in general are well within the permissible limits and hence suitable for domestic purposes. Instead of unregulated rampant borewell development, a well managed plan should be followed to avoid further contamination, degradation and overexploitation of valuable groundwater resource.

ACKNOWLEDGMENT

I wish to express my gratitude to the following:
S.Angchok (Divisional Soil Conservation Officer, Leh) for providing data during early conceptualization phase. Sonam Wangtak for help during sampling phase. Yangchan Dolma (CEO, Education, Leh)[Retd] for providing valuable inputs in early review. Dr. P.K.Naik (Scientist, CGWB, India) for detailed review during final stages. Finally, J.Seb Mankelow for encouragement and general viewpoint.

References

[1] Anonymous 2012. Indian Standard Specification for Drinking Water IS: 10500. Indian Standard Institute, New Delhi, 1 – 31.

[2] Anonymous 2012. Pollution Control Acts, Rules and Notifications, (4th Edn). Central Pollution Control Board, Ministry of Environment and Forests, Government of India, New Delhi.

[3] Anonymous 2011. Standard methods for the examination of water and wastewater (20nd ed.). American

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Public and Health Association, Washington D.C.

[4] Anonymous 2008. Ground Water Information Booklet of Leh District, Jammu and Kashmir State.

[5] Anonymous. Population Growth Rate Calculator-EndMemo. http://www.endmemo.com/algebra/populationgrowth.php. (Accessed 3 May 2015).

[6] Balkhang, H.B. and Dolkar, T. 2014. Work for two major projects begins in Leh; drinking water and sewage. Reach Ladakh. http://www.reachladakh.com/work-for-two-major-projects-begins-in-leh-drinking-water/2390.html. (Accessed 4 April 2015).

[7] Chadha. D.K., 1999. A Proposed new Diagram for Geochemical Classification of Natural Waters and Interpretation of Chemical Data. Hydrogeology Journal, 7 (5), 431-439.

[8] Dolma, K., Rishi, M.S. and Lata, R. (2015). An appraisal of Centralized Waste Water Treatment Plant with Respect to Leh Town. International Journal of Science and Research, 4 (5), 754-759.

[9] Durov, S.A., (1948). Natural Waters and Graphic Representation of their Composition Dokl, Akad, Nauk SSSR, 59, 87-90.

[10] Gjorgievski, M. and Sinolicka, M.T. (2012). Movie induced tourism: A new tourism phenomenon. UTMS Journal of Economics, 3(1), 97-104.

[11] Gondhalekar, D., et al., 2013). Water-related health risks in rapidly developing towns: the potential of integrated GIS-based urban planning. Water International, 38 (7), 902-920.

[12] Herojeet, R.K., Rishi, M.S., and Sidhu, N., 2013. Hydrochemical Characterization, Classification and Evaluation of Groundwater Regime in Sirsa Watershed, Nalagarh Valley, Himachal Pradesh, India. Civil and Environmental Research, 3 (7), 47-57.

[13] Kimura, M., 2013. Past Forward: Understanding Change in Old Leh Town, Ladakh, North India, Norwegian University of Life Sciences.

[14] Lata, R., Rishi, M.S., Talwar, D. and Rikhie, J. 2014. Water Quality Characterization for Drinking Purposes-A Case Study of Sorang Hydroelectric Power Project in DistrictKinnaur, Himachal Pradesh, India. International Journal of Science, Environment and Technology, 3(5), 1843-1855.

[15] Lata, R., Rishi, M.S., Kochhar, N., and Sharma, R., 2013. Socio-economic impacts of Sorang hydroelectric power project in District Kinnaur, Himachal Pradesh, India. Journal of Environment and Earth Science, 3 (3), 54-61.

[16] Naik, P., Tambe, J.A., Dehury., B.N. and Tiwari, A.N. (2008). Impact of urbanization on groundwater regime in a fast growing city in central India. Environmental Monitoring and Assessment, 146, 339-373.

[17] Raksha, A., and Aswathanarayana, L.G., 2013. Selection of Sustainable Sources for Reliable Water Supply Schemes, In the Localities of Abnormal Climatic Conditions. Research and Reviews: Journal of Engineering and Technology, 2 (3), 256-264.

[18] Statistical Hand Book, 2011-12, Ladakh Autonomous Hill Development Council. http://leh.nic.in/pages/handbook.pdf. (Accessed 5 December 2014).

[19] Usha, O., Vasavi, A,. Spoorthy and Swamy, P.M., 2011. The Physcio Chemical and a Bacteriological Analysis of Groundwater in and around Tirupati. Pollution Research, 30 (3), 339-343.

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