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Baseline Study of Drinking Water Quality – A Case of Leh Town, Ladakh (J&K), India

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Abstract

Water is the vital resource on which life sustains and water becomes more valuable in this cold desert part of the northernmost region of India, called Ladakh which comprises of two districts, Leh and Kargil. 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 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 the ground-pit or in 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, and 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 above desirable limit while 10% samples each recorded TDS and EC above desirable limits.

Keywords: Drinking water; Cold desert; Sustainable development; Turbidity; Sewerage

Introduction

"Hydrology" is the science to know the properties, distribution and behavior of water in nature. Among the various needs of water, the most essential need is drinking. Surface water and ground water are two major sources for the supply of drinking water. Surface water comes from lakes, reservoirs and rivers. Groundwater comes from wells that the water supplier drills into aquifers. Demand for freshwater is increasing with rising population, especially groundwater, since its quality is better than the surface water, which is getting polluted with time. Groundwater is about 20% of the world's fresh water resource and widely used by industries, for irrigation and domestic purposes [1]. The quality of groundwater depends upon overall proportional amount of different chemical constituents present in groundwater. Groundwater quality is more significant in the case of Leh Town as this 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.

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. District Leh with an area of 45100 km^2 is the 2nd largest district in India after Kutch in Gujarat with an area of 45652 km^2. As Ladakh is a cold desert precipitation averages around 61 mm/annum and occurs in the form of snow and rain both in winter and summer months respectively [2]. 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.

Leh town: Leh town 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". Leh is about 434 kilometers from Srinagar (NH 1D) and 474 kilometers

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from Manali (NH 21). The town is divided into 21 administrative wards and the relief ranges from highest 4500 m (amsl) to lowest 3250 m (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 have risen from 28,639 according to 2001 census thus recording a growth rate of 7.8%. The town caters to a huge population of army personnel permanently deployed here with an ever surging tourist's population. The tourism industry and army presence is the pull factor for a large floating population of tourists and migrants labourers particularly in the short summer seasons from June to September.

Historical background: Historical background of Leh Town dates back to the 17th 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 [3].

Geology and hydrogeology: Geology and hydrogeology of a particular area determines the groundwater flow and its properties. Rocks of the district is 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 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 [4]. 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 (Figure 1).

Materials and Methods

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 [5]. The samples were collected in the month of May (Pre monsoon) and October (post monsoon), 2013 (Figure 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°C and further analysis completed as per standard procedures. 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 [6], Trivedy and Goel and Central Pollution Control Board, New Delhi [7]. For map making survey of India toposheet no. 52F/12 was used for digitization and GPS (Global Positioning System) device was used for identifying sampling location.

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.

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. 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 [8]. 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 Figure 3a and 3b.

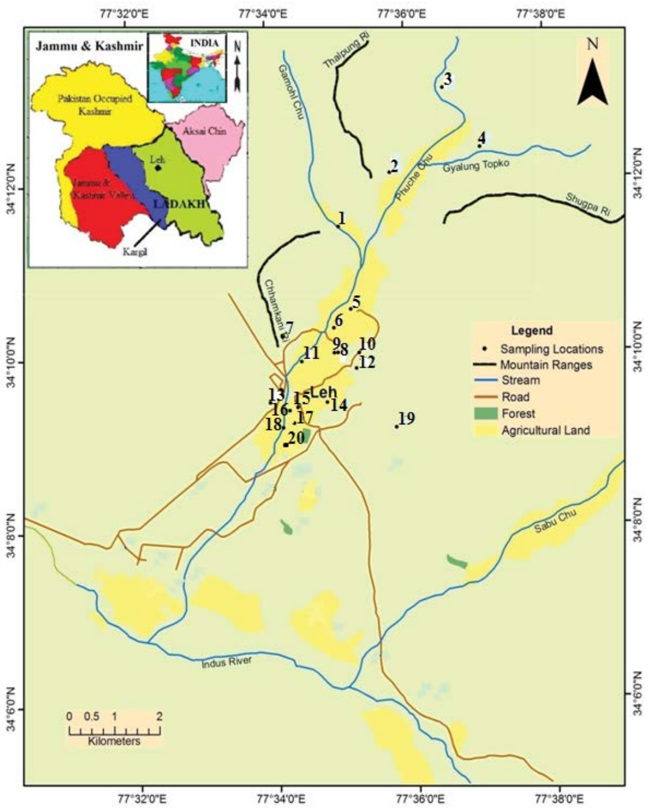

Figure 1: Location map of water sampling stations in the study area.

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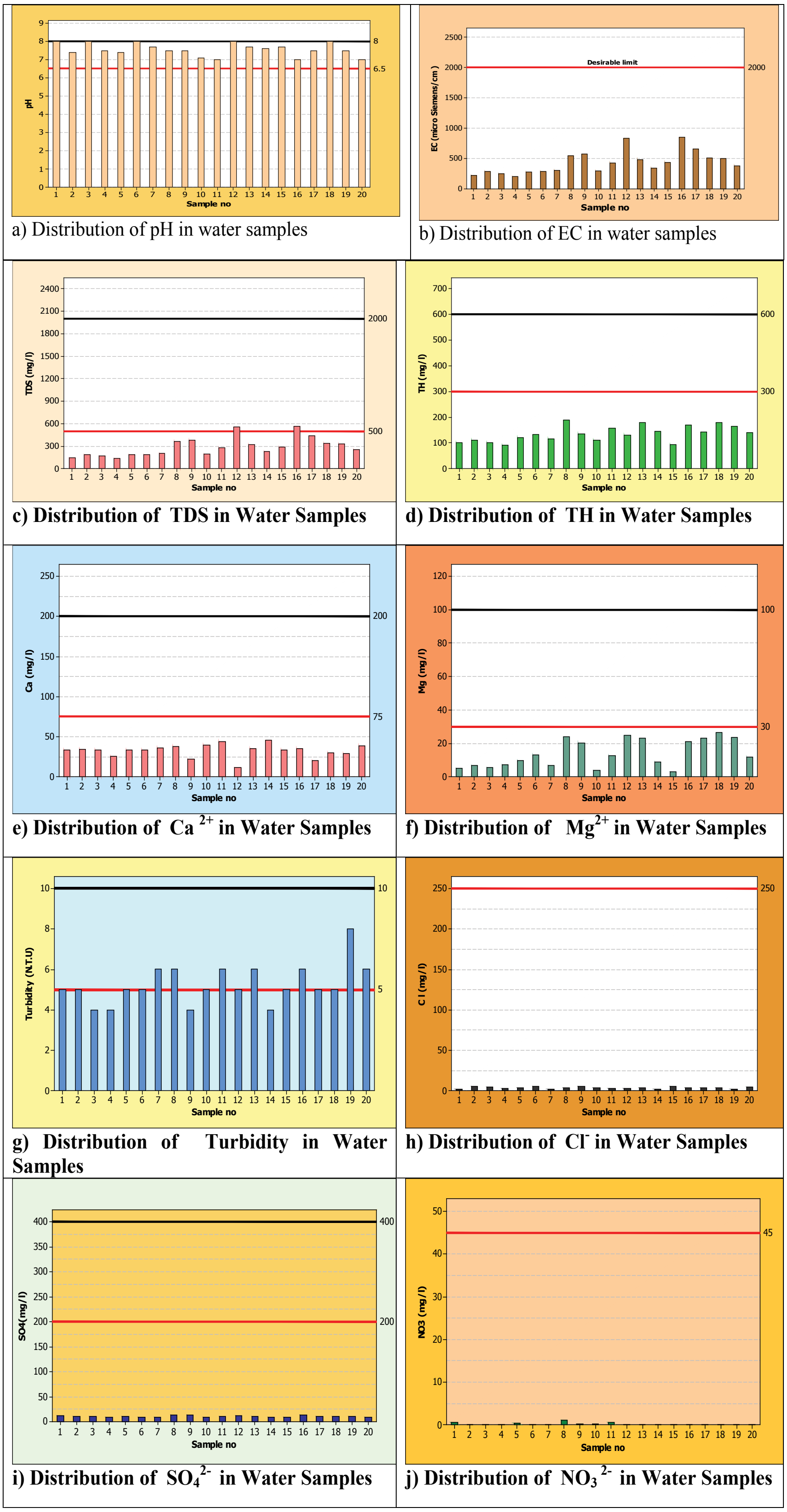

a) Distribution of pH in water samples

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

g) Distribution of Turbidity in Water Samples

h) Distribution of Cl^- in Water Samples

i) Distribution of SO_4^{2-} in Water Samples

j) Distribution of NO_3^{2-} in Water Samples

Figure 2: Distribution of various parameters in analysed water samples in the study area.

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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	600 mg/l	300 mg/l	20	Nil	Nil	90	188	135	30.29
5.	Cl^-	1000 mg/l	250 mg/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	45 mg/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-}	0.1 mg/l	-	20	Nil	Nil	0	0.47	0.06	0.10

*DL- Desirable Limit; *PL- Permissible Limit

Table 1: Distribution of groundwater samples showing various parameters against maximum permissible and desirable limits.

Parameter	Percentage of Samples above	
	*DL %	*PL %
EC	10	Nil
TDS	10	Nil
Turbidity	75	Nil
pH	Nil	Nil
Ca^{2+}	Nil	Nil
Mg^{2+}	Nil	Nil
Na^+	Nil	-
K^+	-	-
Cl^-	Nil	Nil
F^-	Nil	Nil
SO_4^{2-}	Nil	Nil
NO_3^{2-}	Nil	Nil

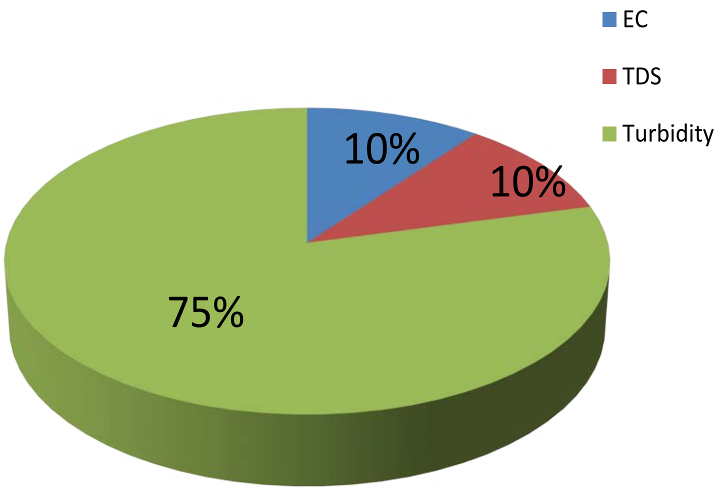

Figure 3: Pie chart showing parameters above bis desirable limit.

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 surface water samples of the study area is depicted in Figure 1.3 (c).

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. Figure 1.3 d shows the distribution of TH in the water samples of the study area.

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

The amount of calcium in the surface water 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 surface water 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. Figure 1.3 e and 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.

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 [9] and are fit for human consumption. The distribution of turbidity at different sampling locations is shown in Figure 3 g.

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 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. Figure 3 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 [9]. Fluoride concentrations in all the water samples were found to be within the permissible limit of 1.5 mg/l Figure 3 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 the concentration of fluoride varied between 0.04 mg/l to 1.30 mg/l with mean value of 0.62 mg/l. Only three samples crossed the desirable limit of 1.0 mg/l.

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 water samples are shown in Figure 3 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.

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. While potassium is an essential element for both plants and animals. 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 purpose as no agency have given any standard with respect to potassium.

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 have been classified as per Chadha's diagram [10]. The diagram is a modified version of Piper trilinear diagram and the expanded Durov diagram [11].

The chemical analyses data of all the water samples collected from the study area have been plotted on Chadha's diagram (Figure 4) and results have been summarized in Table 2. 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.

Conclusion

The complete and systemic study of water quality 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. This fluvo glacial structure bring clastic materials in clay, silt and sand matrix along with glacial melt water in the aquifer system and is 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. Eventually it is concluded that

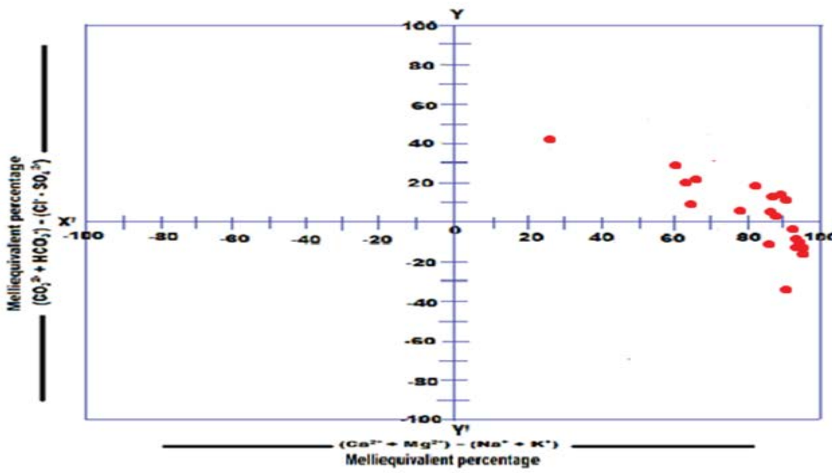

Figure 4: Chadha diagram for groundwater samples.

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^{-})	----------

Table 2: Summarized results of chadha's classification.

the groundwater quality in the study area in general, can be designated as good for domestic and drinking purposes but enforcement of precautionary and preventive approaches required. Instead of unregulated rampant bore well development a well-managed plan should be taken into consideration to avoid further contamination, degradation and overexploitation of valuable groundwater resource.

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