Impacts of Urbanization and Climate Change on Water Quality: A Gender Analysis of Haldwani, Uttarakhand, India.

Introduction

Impact of climate change and urban growth is variable and poses uncertainty to the supply and management of the water resources in the rural as well as urban areas across the country. The Intergovernmental Panel on Climate Change (IPCC) estimates that the global mean surface temperature has risen up to 0·6 ± 0·2°C since 1861, and predicts an increase of 2°C to 4°C over the next 100 years. Increasing temperature would further affect the hydrological cycle in nature either by directly increasing the rate of evaporation of the available surface water as well as by declining the groundwater table (Lobell et al, 2008). They particularly influence the impact on the availability and storage of the water both in surface and subsurface reservoirs (rivers, lakes, springs, and groundwater). The Himalayan Mountain system is dotted with 12 rivers, out of 18 major rivers of the country. Hundreds of small rivulets and thousands of streams make the Himalayas as "Water Bank of Asia". This constitutes 42% of the total of the country. It is ironical that these rivers have not been of any use to the local resident, except for the minor utilities in the form of watermill, occasional irrigation, not exceeding 2% of the total potential use (Joshi 2004). The government scheme of water supply has largely failed due to its inappropriate nature, poor maintenance and distribution. This has plunged mountain residents to severe water shortage, so much so that women and girls have to walk kilometers for potable water. In Uttrakhand, out of total 16000 villages 8800 vilages have been placed as water scarce villages. The districts like Almora, Pauri, Tehri, pithorgarh and chamoli are facing drinking water crisis. 72% women and 14% children have to bear the responsibility of carrying portable

water. The average 60% women have to walk ½ km while 10% of them walk 4 km for fetching water (Joshi 2004). Urban growth and climate driven changes impart a significant role in distribution and consumption of water in the urban areas. Urbanization, widely recognized phenomenon, is dramatically altering the demography, economy and different related activities of a developing country (M C Granahan and Sattethwaite, 2014). However, urbanization also has adverse environmental implications such as deforestation, industrialization, as well as adverse impact on the quantity and quality of natural resources like water, soil, air, forests etc (Grumbine et al, 2009). While climate change affects the water resources directly though changes in climatic variables like air temperature, precipitation, and evapotranspiration, the relationship between changing climatic variables and urbanization together with their impact on surface and subsurface water resources through an economic, environmental and social lens, is poorly understood. India has a unique climate where the monsoon season dominates; with the major physiographic feature driving the monsoon is India's location on the globe The Himalayas, the central plateau, the Western and Eastern Ghats and the ocean surrounding this (Mall et al, 2006). The Indian Himalayan region being one of the most climate sensitive regions of the country is highly vulnerable to the impact of climate change and urbanization. Uttarakhand, a vital segment of the Himalayan Regime is most affected to the climate mediated risks. The hilly regions of the Himalaya are facing problems in terms of urban water scarcity due the changing climate in the state (Joshi, 2004). Haldwani, being the second most urbanizing town of Uttarakhand after Dehradun, and is likely to face the impact of climate change on the current water resources. The crippled water supply is leaving an adverse impact on the quantity and quality of water in the city when the people are gearing up for their day to day water needs. Unlike many other areas, Haldwani region has plenty of drinking water in store. According to the official concerned of the

Jal Sansthan, Haldwani. While availability of the drinking water remains about 35 million liters per day (MLD), the demand for the same is only around 28 MLD even during the peak hours, thus showing about seven MLD drinking water in surplus. Besides, the Jal Sansthan has also installed tube-wells in many parts of the city. Yet, the drinking water crisis continues hitting lives for long. This is mainly because of delay in replacing over four/ five decade- old drinking water distribution system of the Haldwani region and poor storage capacity. More so, excessive dependence on tube wells only aggravates the drinking water crisis as once a tube well becomes non-functioning it takes more than a fortnight to put it back on the rails, as the officials concerned maintain. Though the officials concerned have expressed hope for early restoration of the drinking water supply to these areas, patience of citizens of the affected areas seems to be wearing thin each passing day. 'Indifferent' attitude of the public representatives of the Haldwani Assembly constituency as the affected citizens alleged has compounded on their woes. Daily unscheduled power cuts coupled with low voltage has added to the woes of the people of the region which is dependent on power- driven drinking water distribution system like tube-wells to a great extent (23 October 2014, PNS, Haldwani). The declining availability of water supplies is one of the most important environmental issues facing various countries at the present time. It has been estimated that nearly two-thirds of nations worldwide will experience water stress by the year 2025 (United Nations Environment Programme 2002). Climate change, affluence and population growth have resulted in vast requirements of water for use in domestic, industrial and agricultural settings.

Water is critical to the livelihoods and well-being of the world’s population but millions suffer from lack of access to clean water, inadequate water for food production and the effects of pollution and environmental change. Increasingly, improved water supply management is seen as

centrally important to poverty alleviation and to ensuring a sustainable future for millions of people with vulnerable livelihoods in marginal environments. The impact of inequitable access and poor management is huge. The United Nations reports 1.1 billion people (one in six of the world's population) lack access to improved drinking water, and 2.4 billion lack sanitation. As a result, the burden of death and disease related to inadequate water is high, with an estimated mortality of 3 million people a year, and millions more suffering water-related diseases. The majority of those affected are likely to be children under five years old, affected by diarrhoeal disease.

It is therefore imperative to, quantify the availability of water resources (both groundwater and surface) and understanding the impact of climate change and urban development that alters and influences quality as well as quantity of the same is significant. The aim of this study would be to get an in-depth understanding of the various water sources of the city of Haldwani, the impact of climate change on the those resources both in terms of quality and quantity with a focus on the rapid urbanization of the city. As literature also suggests that climate change impacts have a strong gender component to itself, this study would also focus on the changing water quality with respect to differential access to various groups like men, women and children and the health impacts of the same if any via a detailed analysis on the quality of the drinking water in the city of Haldwani in of Uttarakhand, India.

Literature review:

Previously very few studies have documented the impact of climate change and rapid urbanization on the quality as well as quantity of the various water sources in Uttarakhand with a main focus being on gender. Joshi et al (2011) in his paper "Caste, Gender and the Rhetoric of

Reform in India's Drinking water sector" have documented that the Himalayan Mountain ecosystem is dotted with 12 rivers, out of 18 major rivers of the country. But, it is ironical that these rivers have not been of any use to the local resident, except for the min or utilities in the form of watermill, occasional irrigation, not exceeding 2% of the total potential use. The government scheme of water supply has largely failed due to its inappropriate nature, poor maintenance and distribution. This has plunged mountain residents to sever water shortage, so much so that women and girls have to walk kilometers for portable water. In Uttarakhand, out of 16000 villages 8800 villages have been placed as water scarce villages. The districts like Almora, Pauri, Tehri, Pithorgarh and Chamoli are facing drinking water crisis (Joshi et al, 2004). In a more recent study M C Granahan and Sattethwaite (2014) reported that there is an emerging consensus that urbanization is critically important to international development and ends with a brief review of urbanization and sustainable development, concluding that although urbanization brings serious challenges , attempts to inhibit it through exclusionary policies are likely to be economically, socially and environmentally damaging.

Rawat et al (2012) carried out a cross-sectional study to assess the bacteriological quality of water in Haldwani block, Nainital District, India and stratified random water sampling from the various water sources of city (river Gola, Tube wells) and water treatment plant. In total 108 samples were collected and tested for Coliforms by the most probable number technique and found that the water from river Gola was highly contaminated, while the water from Tube wells were unsatisfactory and more than half of the tap waters were polluted. Bacterial contamination of water treatment plants and their supplies indicates significant disparities in the efficiency of water treatment processes. Contamination of water taps of the tube wells suggested leakage of pipes. Tambe et al (2008) conducted a one year longitudinal study on bacteriological quality of

the rural water supply system. In this study 313 water samples from different sources such as well, tanks, community standposts, Handpumps, percolation lakes, and streams from households were collected from six villages in Maharashtra and tested for coliform counts. As a result of this study, 49.8% of the total samples were found to be contaminated along with 45.9% of samples from piped water supply were found to be polluted. The reason behind this contamination was irregular and inadequate treatment of water, lack of drainage system, and domestic washing near the wells lead to the deterioration of the water quality. Payment et al. conducted two epidemiology studies (Payment et al, 1991; Payment et al, 1997), each suggesting that the distribution system was at least partially responsible for increased levels of gastrointestinal illnesses. The studies examined the health of people who drank tap water and compared the group to people receiving water treated by reverse osmosis to determine which group had higher levels of gastrointestinal illness. Both studies pointed to the fact that people who drank tap water had increased cases of gastroenteritis. WHO & UNICEF 2000, have documented that an urban water supply may become contaminated prior to consumption, from untreated water (either intentionally untreated or through treatment failure) or from cross-contamination in the distribution system after treatment occurs. Either or both of these mechanisms can result in poor microbial quality of the water supply and may result in diarrhoeal disease and other gastrointestinal illnesses when ingested. There is evidence suggesting that distribution networks contribute to decreased water quality. For example, in La Plata, Argentina, intestinal parasites were detected in tap water sampled from four regional zones, but no parasites were detected from samples taken in the immediate vicinity of the plant (Basualdo et al. 2000). Similarly, in Mexico City, bacteriological contamination increased by 26% from the point of treatment to the consumer's tap (Gaytan et al. 1997). Finally, in a Trinidadan community, 80% of house-hold tap

water samples tested positive for total coliforms, while no samples from the treated reservoir tested positive (Agard et al. 2002).

Rationale:

It is anticipated that urbanization along with its related developmental activities is likely to act as a driver or a trigger that contributes to the increasing temperature and changes the climatic variables disturbing the Mountain ecosystem and its services. An estimated one-tenth of the human population derives their life-support directly from mountains. In addition to this, the population living in the valleys and plains depend on the mountains for water. The vulnerability of mountain areas to changing climate coupled with the pressure exerted by increasing population makes it as "weather sensitive and fragile ecosystem" as the mountains are still evolving.

Great concern has been expressed about backwardness of the Uttarakhand region. It is true that the environment of the region has degraded, forests have disappeared, many small streams and springs have dried up, agricultural holdings are hardly able to sustain the local population, traditional occupations have sharply diminished and new jobs are almost non-existent leading to migration to the plains. At the same time, it is also true that the region has never had a shortage of water resources. Himalayan springs on which people depend, have dried up due to interference in their natural recharge caused mainly due the changes in the climatic variables such as air temperature, precipitation and evapotranspiration. Over the last half-century, there has been a growing trend of population settlement in urban areas. Currently, the greatest migration rates from rural into urban areas occur in developing countries. The United Nations has predicted that, by the year 2030, 56% of people in developing countries will reside in urban

areas (United Nations Population Division 2002). As urban populations will continue to expand, the demand for delivery of clean drinking water would also increase and subsequently the impact that distribution networks have on reducing water quality has been inadequately addressed due to the limited information available on the magnitude of the public health problem. Existing statistics are often optimistic rather than realistic estimates of the actual conditions of distribution networks. Little research is being conducted towards determining whether distribution system inadequacies are a result of sporadic breakdowns or are continually occurring. Moreover, very few epidemiological studies have been published on disease outbreaks in relation to distribution network deficiencies in developing countries. Hence, there is a vital need for further research on drinking water distribution systems in developing countries.Therefore, it is important to consider the potential impacts of climate change and urbanization on groundwater system, its distribution and consequent health impacts that communities are likely to face in the city of Haldwani both in terms of quality and quantity with a gendered lens.

Objectives:

To develop an in-depth understanding of the water supply system of the city of Haldwani including surface as well as sub-surface water sources.

To determine the impact of climate change and urbanization on the quality of the water in Haldwani.

To examine the gender sensitive health risk or health impacts associated with the quality of the water in the city.

To provide appropriate recommendations or suggestions related to water supply system, management and water quality depending upon the relative findings of the study.

Methodology:

Study area

Haldwani is a tehsil head-quarter of Nainital District and situated at a distance of 275 km from the National capital of New Delhi on Delhi-Nainital road. The nearest air port is Pant Nagar at a distance of 20 km. Haldwani lies between $29^0$21'6 to $29^0$13' North longitudes of $70^0$51'67 - 79^0 31' East latitude. Its average elevation is 424 m. The town is about 1062 sq km. Haldwani is well connected by road network to Delhi and Lucknow. The railway stations of Haldwani and Kathgodam fall in the limit of Haldwani-Kathgodam. Geologically, it is settled on a piedmont grade (called ***Bhabhar***) where the Mountain Rivers go underground to re-emerge in the Indo-Gangetic plain. Bhabhar is a level surface zone at the foothills of the Himalayas 34 km wide where the Himalayan rivers and streams disappear under boulders and gravels due to the porous soil and sub-soil composition of Bhabhar. As a result, the underground water level is very deep in this region. Haldwani is the last outpost of the plains. From here the road climbs, temperature drops with every meter of altitude and winds through the hill towns of Uttarakhand to the far reaches of the Himalayas. City gets a fair amount of sun but the harshness of the plains summer is eased by the cool evening breeze from the Gaula River and any fluctuations of weather in Nainital affect Haldwani.

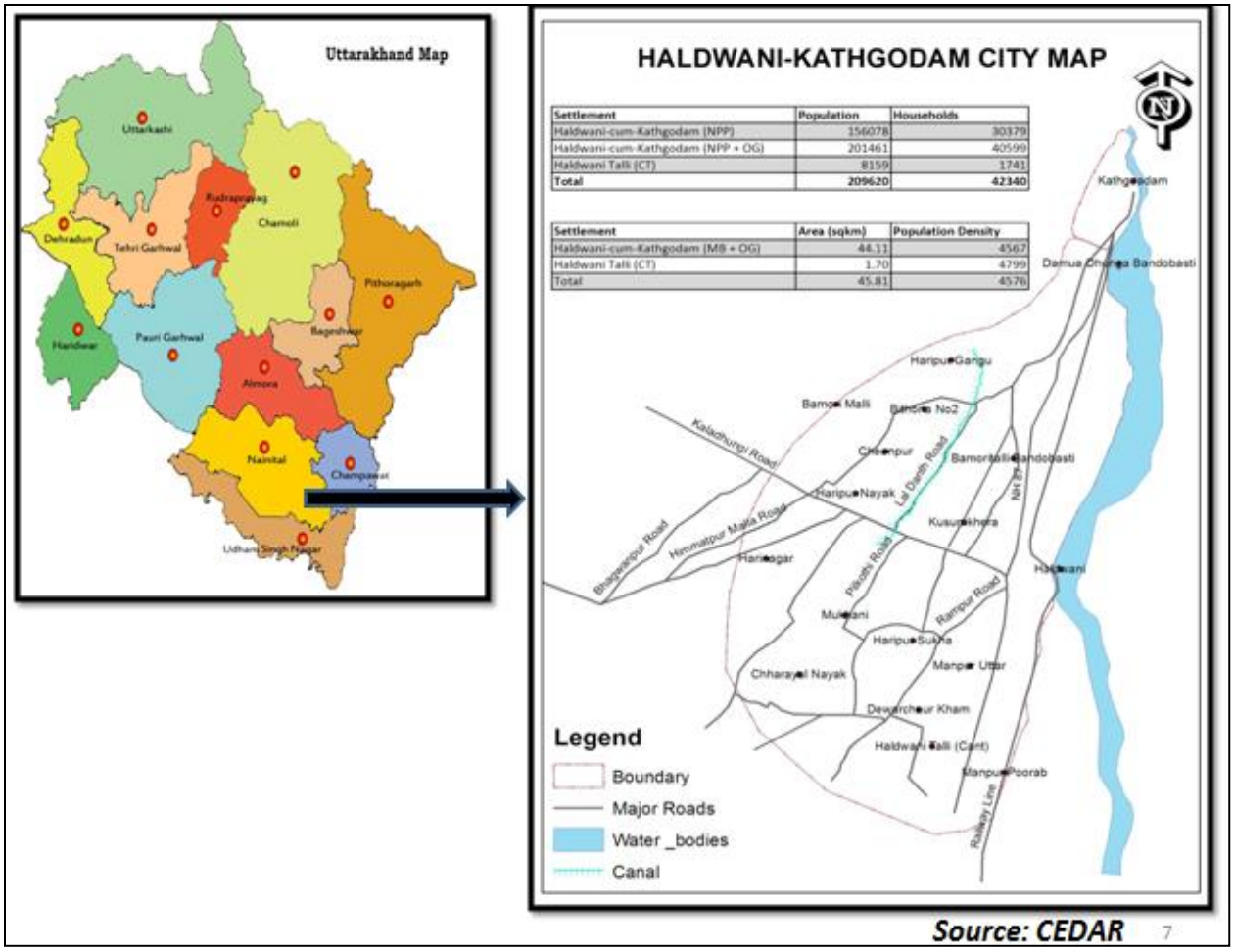
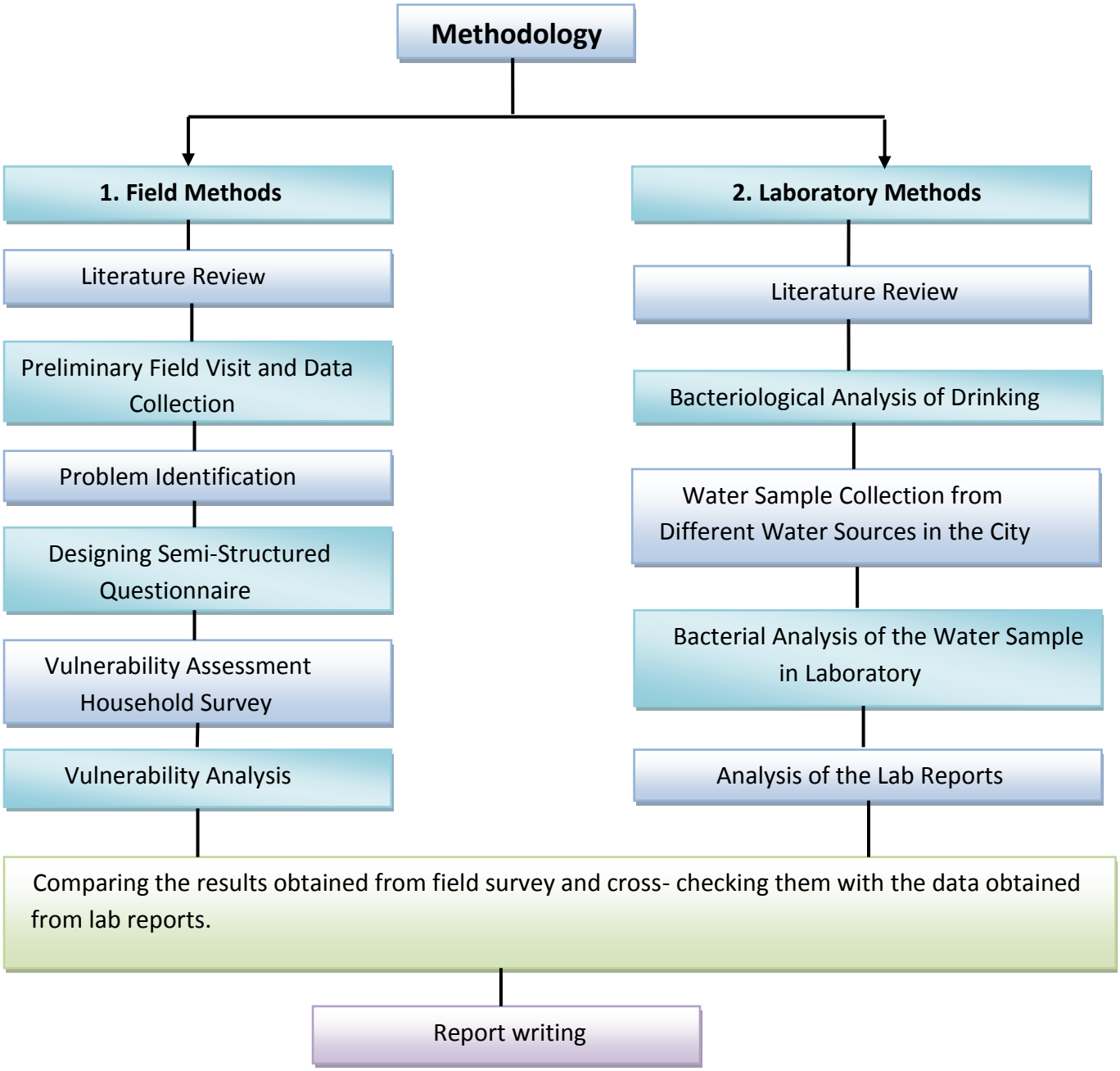


Figure 1. Geographic location of Haldwani (Uttarakhand)

The minimum temperature varies from 5^0-10^0C and maximum from 38^0– 42^0C. Average annual rainfall recorded is approximately 1,505 mm. Haldwani is divided in to 25 wards and these wards are further divided into 65 municipal wards sanitation committees. All the wards and sub wards come under Nagar Nigam. However, it has been ranked as a first class municipal corporation. Haldwani-Kathgodam Municipal Council was established on September 21, 1942. Currently it is the second largest Municipal Council in the state of Uttarakhand after Haridwar. Municipal Corporation is working on the problems related to water and electricity supply.

Research Methods:



Newman and Benz in one of their book "*Qualitative and Quantitative Research Methodology*" has explained that Qualitative and Quantitative research strategies and their underlying presuppositions have been increasingly debated since the early 1980's, as though one or the other

should eventually emerge as superior. I as a researcher did not want to treat the subject of the study to be treated as the object where the aim would have been to only draw information and knowledge from the subject, in this case being the collectives. The type of methodology that I had adopted for this study is the 'participatory action research' that explains the position that the two philosophies mentioned above are neither mutually exclusive (i.e., one need not totally commit to either one or the other) nor interchangeable (i.e., one cannot merge methodologies with no concern for underlying assumptions). Rather I tried to present them as interactive places on a methodological and social continuum. The type of methods I have designed to carry out my work is categorized broadly into two sections- 1. Field methods and 2.laboratory methods. For any study, especially an exploratory one like this, at the epicenter lays its methods and methodology. Hence, a detailed wording of the methodology is extremely crucial and needed.

Field Methods:

Field methodologies widely consists of a preliminary visit to the proposed study area and collecting the basic information about the study sites, understanding the existing environmental conditions preceded by problem identification prevailing in the society. Before the drafting of the questionnaire, secondary literature was reviewed and the questions were based on various frameworks. The method of primary data collection identified to be used was the ethnographic method. Ethnography is a holistic approach to study cultural systems. It is a process of discovery, of making references and continuing inquiries in an attempt to achieve validity. And the most important aspect of ethnography is that it is an open emergent learning system where the researcher has a certain space of freedom as opposed to that of a rigid investigative approach **(Whitehead, 2005)**. The tools that were used were semi-structured interviews, participant observation, vulnerability assessment household surveys and focused group discussions.

Vulnerability Assessment Household Surveys and FGDs:

Figure 2. Vulnerability assessment household survey in Rajendra Nagar and FGD in Dholakbasti.

In the present study, a **Water Vulnerability Index (WVI)** specific to mountainous settings has been used. The WVI will provide a realistic approach to recognize climate change urbanization and climate change vulnerability role on water resource at the community level in an urban setting in light of various interacting fabrics of social and economic relationships. The proposed vulnerability index comprises various dimension of vulnerability by including three major components like Adaptive capacity, Exposure and Sensitivity. Components are case specific and may be qualitative characteristics of the system with the potentiality of expressed as quantitative factors through the use of proxies (Deems 2010). Each component contains relevant subcomponents based on the specificity of the livelihood requirements and environment of the study area. These parameters 9indicators as well as sub-indicators) is used to define various components as well as the indices required to address the issue. Indicators for the major components and sub-components based on the specificity of the system (community) are used to determine the vulnerability score.

WVI uses the primary data from household surveys and FGDs to construct the index and presents a framework for grouping and aggregating indicators. The desired information due to urban growth and climate change revolves around the various dimensions such as: socio-economic factors, major barriers in accessibility to water, water quality and sanitation and water borne health impacts.

The study area is stratified on the basis of the development and approach to the community members. A total of 65 household surveys were conducted from two socio-economically weak wards in the area namely: Rajendra Nagar (ward no.02) and Dholakbasti (ward no.22). From Rajendra Nagar, Three sub-wards were selected and from Dholakbasti, two sub-wards were choosen for the Survey. From these sub-wards households were selected at the random to collect the data through questionnaire. The survey questionnaire consisted of three broad sections: Exposure, Sensitivity and Adaptive Capability. The Exposure section contains information pertaining to 'Climate variability', however Sensitivity consists of 'Health impacts' and 'Water'. At last the Adaptive Capability includes Socio-demographic profile, Livelihood strategies, and Social networks. Depending upon all these parameters the vulnerability of the area is calculated as follows:

$$\text{Adaptive capacity} - \text{Sensitivity}$$
$$\text{Exposure}$$

After the collection of primary data, with the help of the different frameworks, analysis was worked upon by looking at the different components of the qualitative data collected. There were a few components which were quantitative in nature and these were incorporated using MS Excel and again analyzed.

Laboratory Methods:

A cross sectional method is conducted to assess the Bacteriological quality of water in Haldwani. It includes collection of the water samples from various water sources in the town (River Gola, Sheheetlahat Gadhera), water treatment plants (Sheetlahat WTP and Sheeshmahal WTP) and from different households. Samples are then tested for coliforms by the most probable number technique **(Rawat et al 2012)** from the microbiology department of "Government Medical College, Haldwani" and then identification of the species would be done by standard procedures. Lab reports is then analyzed thoroughly and compared with the data collected from the household surveys and secondary literature depending upon which results are concluded.

Collection and transport of water samples:

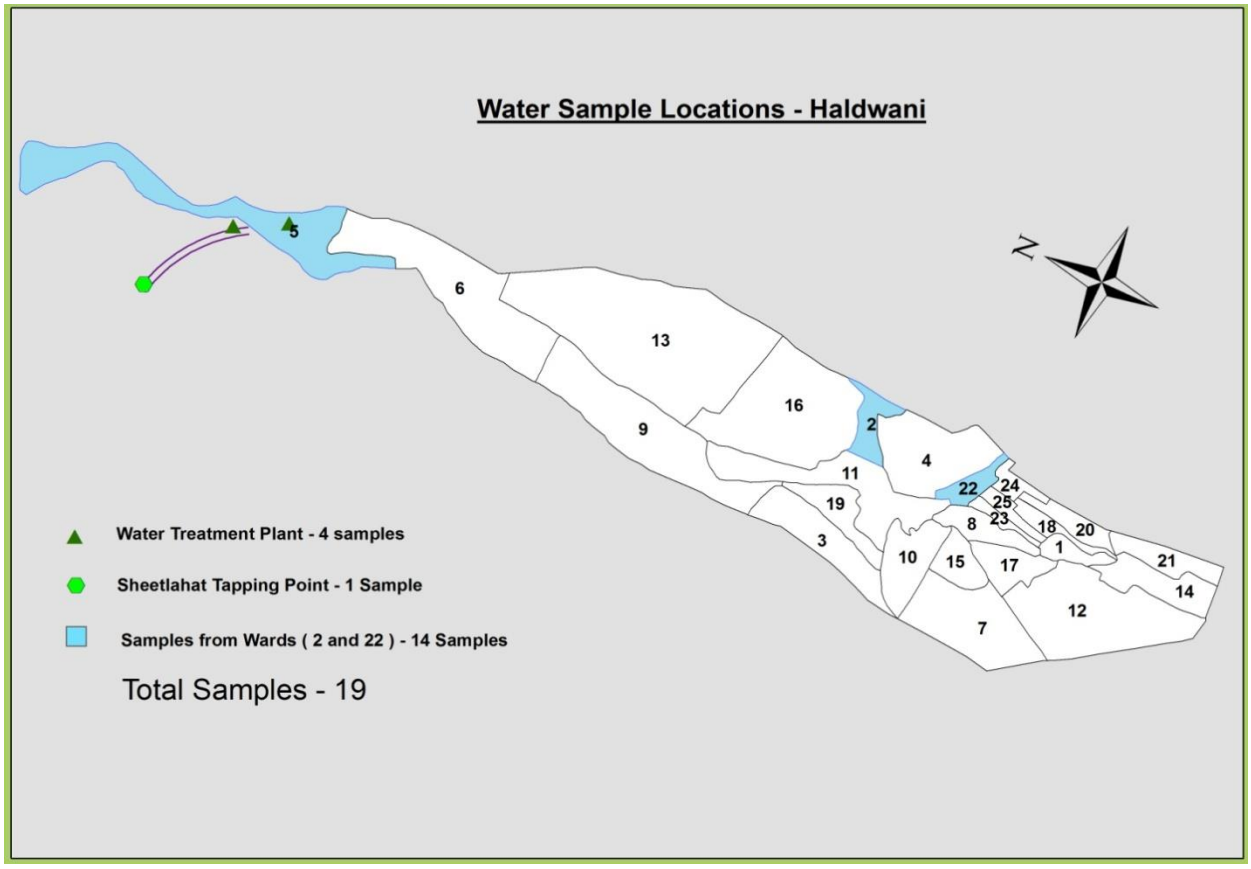


Figure 3. Water sample collection locations in the city.

Sampling was done during the month of May 2017. Field workers of CEDAR were trained at the MGS (M.G.Sahani and Co.Delhi Ltd.), a reputable industry in Dehradun to collect the water samples using the standard protocol. A total of 19 water samples were collected in 100-ml sterile plastic bottles from the respective sources i.e. 1 sample from sheetlahat tapping point, 2 samples from sheetlahat water treatment plant, 2 samples from sheeshmahal water treatment plant, 2 samples from Tube well of Rajendranagar (one with covered utensil and one with uncovered utensil), 6 samples from the households of Rajendranagar, 1 sample from the Tube well of Dholakbasti, and 4 samples from the households of Dholakbasti. Once done with the sampling, the samples were then transported with freezer packs and dry ice within 24 hours to the lab for testing.

Figure 4. Water sample collection from different sources.

Bacteriological Testing: Samples were tested for coliform count by the Most Probable Number technique. As per the Bureau of Indian Standards, samples with 0 coliform/100 mL of original water are to be considered excellent, with 0-10 coliform(s) as acceptable, and above 10 coliforms as polluted.

Observation:

Main water supply sources in Haldwani.

There is adequate availability of water sources (both ground water within city and surface water on periphery of the city). Total production capacity of treated water is 56.70 mld but actual production is 38.40 mld due to withdrawal constraints from Irrigation Department in Gola canal and lack of adequate pumping in Gola head works. Haldwani mainly receives water from three sources, which are *Gola River* and *Sheetlahat spring* and *Tube wells* (fig.5).

1. Gola River: The main source of water supply is the Gola River. The raw water intake for this source is about 1 km downstream of the Gola canal head works. The design discharge is 930 million liters per day (mld), out of which only 28 mld water is allowed for drinking purposes. (*Executive Engineer (EE). Irrigation Department Haldwani letter no.3626/skhh/misc camp dated 20-12-2010 and E.E. Jal Sansthan, Haldwani letter no.4183/Haldwani nagar/144 Dated 21-12-2010*). The main source of water is combination of ground and surface water.

2. Ground water: In Haldwani, the groundwater is being extracted by tube wells to provide 56% of the current total water production. There are 13 nos. working tube wells with total rated discharge of 18.72 mld. Additional 4 nos. tube wells are being installed by UPJN (Uttarakhand Pay Jal Nigam) with total rated discharge of 5.32 mld. Past records (maintained by UPJN / UJS) has not shown decline in the discharge of the tube wells. Existing tube wells are in good condition and do not require any rehabilitation. The Central Ground Water Board or any other organization of the related field does not have the data of capacity/recharging rate of the ground water table of Haldwani. However, the UJS and UPJN informed that there is no depletion of the ground water levels in the tube wells.

Table 1: Status of tube wells in Haldwani

Tube Wells: (Existing)	
Total number	13
Average life	40 year
Average depth	200 m
Total design yield	1.72 MLD
Tube well (Under construction by Pey Jal Nigam)	
Total number	4
Average depth	200 m
Total anticipated yield	5.32 MLD
Quality and treatment	Good, only chlorination
Operating hours per day	16 hrs
No. of tube wells needs redevelopment	**Nil**

Source: ADB Sub-project Appraisal Report, 2011

3. Surface water: Sheetlahat spring**,** another source of water is the Sheetlahat Spring. However, this source has been depleted to a negligible level.

Figure 5. Water sources of the city. a) River Gola, b) Tube well, c) Sheetlahat spring.

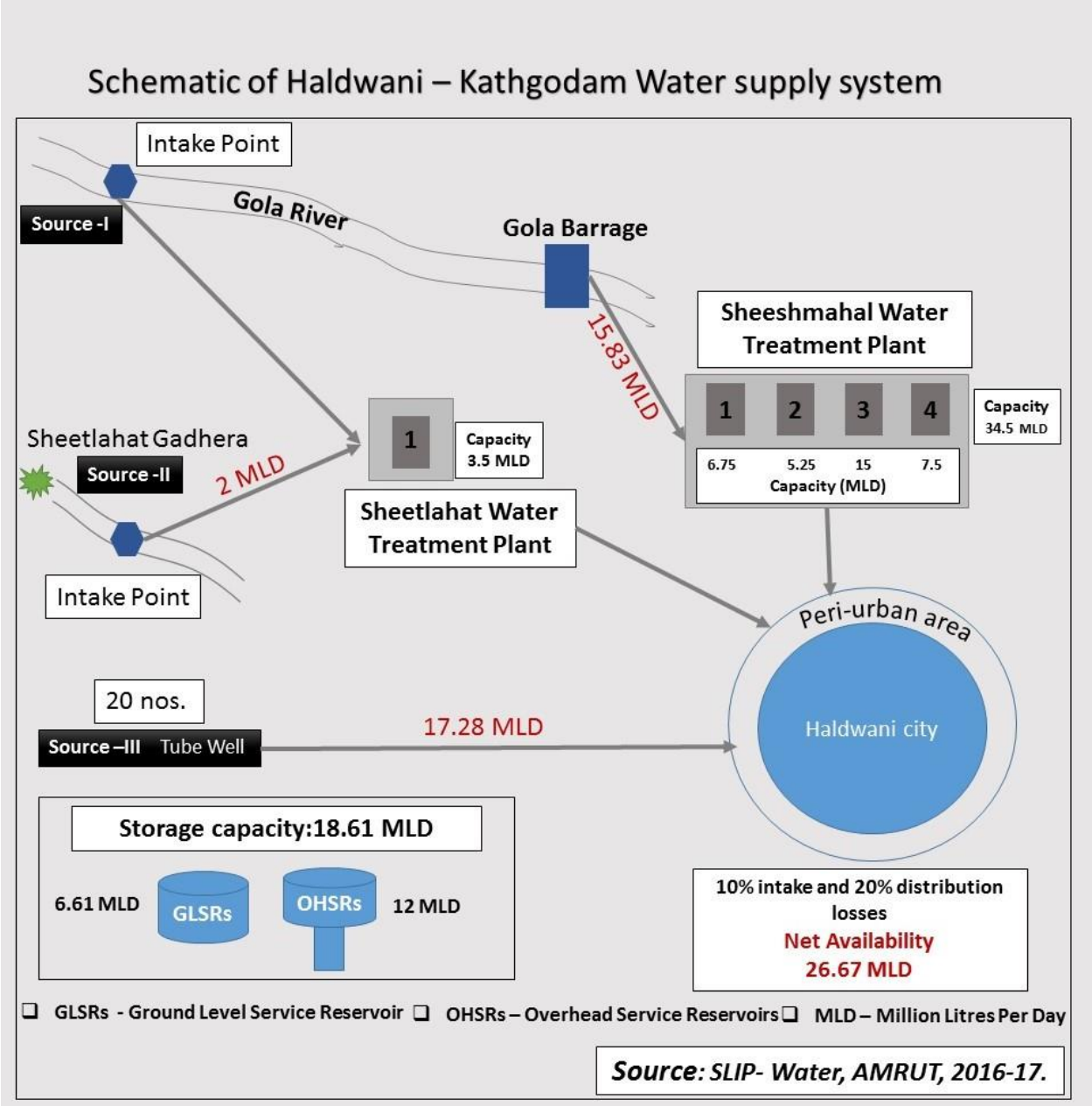


Figure 6.Schematic of Haldwani-Kathgodam water supply system.

At present, there are three main sources of water for Haldwani-Kathgodam Township including the surface water from **Gola River**, groundwater from **Sheetlahat Gadhera** and sub-surface water from **Tube wells**. River Gola is adopted as source of drinking water for Haldwani town and about **15.83 MLD** water from the river is diverted towards Sheeshmahal Water Treatment Plant passing through Gola Barrage. Water at this treatment plant gets filtered in four filtration

units having water capacities of 6.75MLD, 5.25MLD, 15MLD and 7.5MLD respectively. Similarly, about **2MLD** water from Sheetlahat Gadhera is diverted towards Sheetlahat Water Treatment Plant. The designed capacity of both the treatment plants i.e. Sheeshmahal Water Treatment Plant (constructed in the year 1975) and Sheetlahat Water Treatment Plant (constructed in the year 1962) is 34.5 MLD and 3.5 MLD respectively. In addition to the other 2 sources mentioned above, **17.28MLD** water is drawn through a total number of 20 Tube wells located in different wards of the city. After considering 10% intake losses at both the treatment plants and 20% distribution losses, the net availability of water in the town is **26.67 MLD**. Treated water from both the treatment plants together with the water from tube wells through piped water supply caters to the water demand of Haldwani-Kathgodam Township as well as the surrounding Peri-urban areas (Fig.1).

All the water supply to the town is lifted and stored in reservoirs from where the water is supplied to all the wards. The total storage capacity of the reservoirs is **18.61 MLD** of which the storage capacity of GLSRs and OHSRs is 6.61 MLD and 12 MLD respectively (SLIP-water, AMRUT, 2016-17).

Sheetlahat Gadhera:

Sheetlahat Gadhera is located on the western side of Haldwani – Nainital road near Kathgodam railway station. The Gadhera emerges from the Sheetlahat spring located deep into the forest. Sheetlahat is the traditional water source for Haldwani city since decades. In the past, it was only the source serving to the entire city's population. British have identified this gadhera and made a beautiful and systematic tapping infrastructure which includes two small treatment units and one filter house.

The System:

Intake point:

The intake point of Sheetlahat Gadhera is located at a distance of half a kilometer from the filter house. The Origin of this gadhera is not identified. About more than half of the water from spring flows through this point and gets diverted in to two treatment units, situated before the filter house, in which the water is collected for phase 1 treatment.

Phase 1 treatment:

The treatment method in these two units is different from each other. In the first unit, there are six chambers designed in columns of two and rows of three. Collected water enters into the first two chambers through sink holes where the water stays for some time. Then it moved into the next two corresponding chambers from the bottom. Water stays in these two chambers for some more time and then flows into the remaining two chambers. These chambers are basically the **"settling chambers"** and due to the settling down of water in them, dust or waste particles present in the water floats at the surface which can be easily separated and then the water is diverted towards the filter house through the pipelines.

The second treatment unit is designed with two chambers and two circular structures constructed in between both the chambers. The design is structured in this way to catalyze the process of increasing oxygen content of the water (fig.2). Therefore, water entering into this unit gets up welled in both the corresponding chambers. Out of the two chambers, one has an inclined boundary to allow the passage of water into the distribution pipelines via gravity extending upto the filter house, while the heavy dust particles settle down at the bottom of the chamber. This process of natural de-siltation ensures better quality of water.

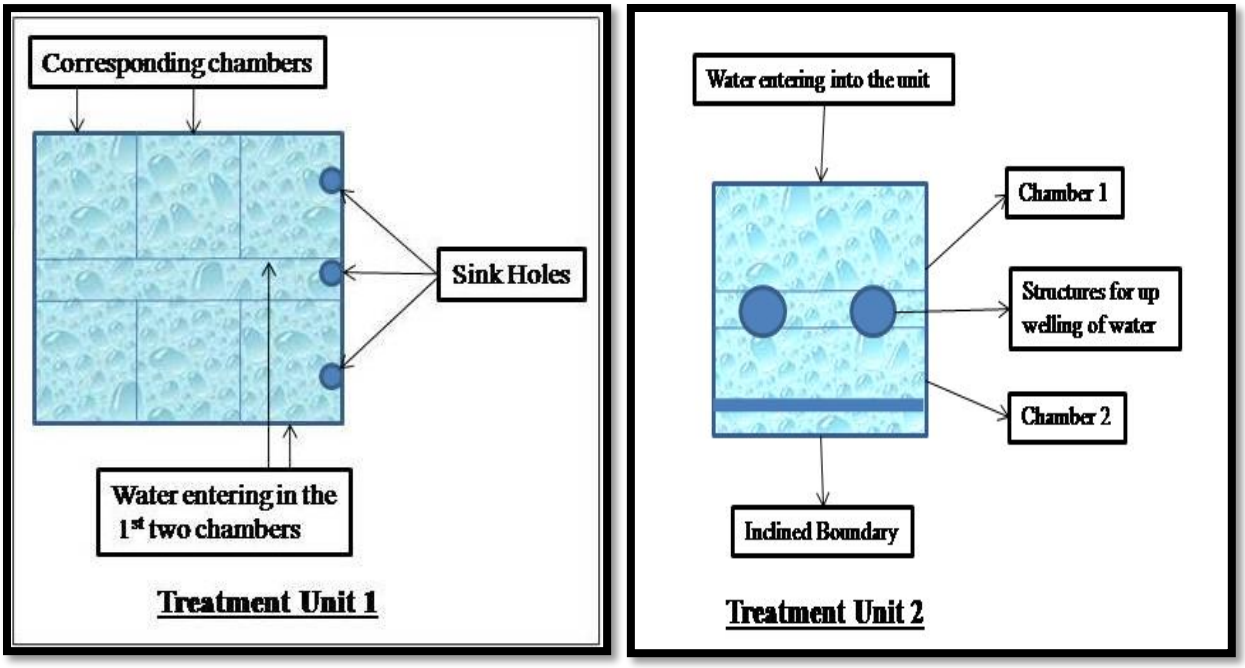


Figure 7.Schematic showing water filtration in Treatment unit 1 and unit 2 (phase 1 treatment).

Phase 2 treatment

Sheetlahat filter house:

History: The plant was established by a team of British from Calcutta in the year 1955-1956, but inaugurated in the year1962 with a total capacity of 62,000 gallons. Initially it was only the Sheetlahat Gadhera that supplied water to the filter as per then water demands of the population. But due to the process of urbanization which led to increase in population, pressure on required water quantities increased thus leading to an increase in demand. To meet the water requirements of this increasing population, water was then lifted from River Gola in the 1970s.

Earlier, the water from this plant was supplied to only Kathgodam as well as Army cantonment which spanned a distance of about 8 kms to a population of about 2 lakhs.

Structure and treatment: Inside the filter house, there are 2 small and 2 big sized inlet pipes to uplift the water from Sheetlahat Gadhera and Gola River respectively. Two (1 small and 1 big) of these 4 pipes are for backup option when other inlet pipes becomes dysfunctional.

The filter house receives water from SheetlahatGadhera 24×7 a day while from River Gola during 10AM to 7-7:30PM every day. A total of 2 MLD water is being lifted each day from both the sources.The collected then flows into an obstructed channel (to decrease the pressure) to the chambers (2 in nos.) where the water is aerated by a compressor motor located aside. The unclean water in the aerated chambers is drained out through the holes present at the bottom and the clean water is processed with chlorine in the chlorination house. This chlorinated water is then diverted to the storage tanks (GLSRs) (2 in nos.) located in the premises. Each day about half kg of bleaching powder is used for chlorination. The treated water from GLSRs is channeled to the pump house from where water is getting distributed through pipelines. (Source: Akash singh, Operator)

Present status: Currently the water from the Sheetlahat Filter house caters to only the water demand of the Kathgodam area. Located close to the filter house, there are three GSLR's which were constructed by the Jal Nigam, out of which two are handed over to the Jal Sansthan for their functioning while the other one is still under jurisdiction of the Jal Nigam. Once this particular GSLR is handed over to the Jal Sansthan, it would cater to more storage capacity to meet the ever increasing demand of water. These tanks are connected to distribution mains which is the central pipeline responsible to provide water through sub connections.

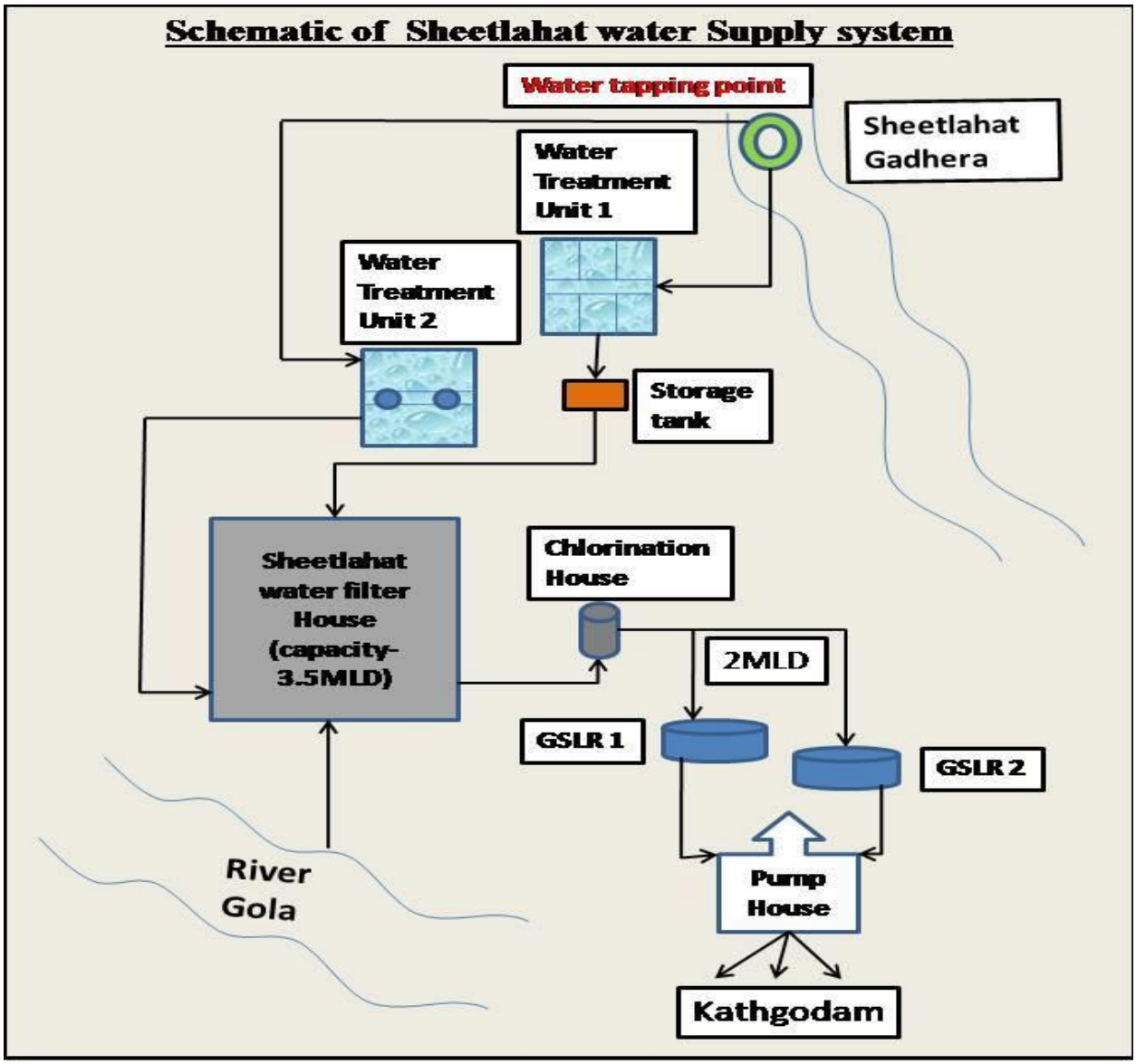


Figure 8.Schematic of Sheetlahat water supply system.

Sheeshmahal Water Filter House

Sheeshmahal water filter house is located on the western side of Haldwani – Nainital road near Kathgodam railway station. Along with the 20 functional tube wells, it caters the water demand of the Haldwani city and the surrounding peri urban areas.

History:

Sheeshmahal filter house was built in the year 1962. With respect to Haldwani the initial arrangement of water supply was made from Shitlahat gravity water source. But later , the demand of water got highly increased due to the increase in population and fast development of the city. Hence, this water filter house was constructed to meet the increasing water demand in the city.

The system:

Water from River Gola is taken up through a grit chamber, from where it flows by gravity through pipelines to a further distance of about 1 km up to the main water works located at Sheesh Mahal for treatment. The water filter house consists of four treatment units- unit 1, unit 2, unit 3, and unit 4 with their individual water capacities of 1500 MLD, 500 MLD, 600 MLD and

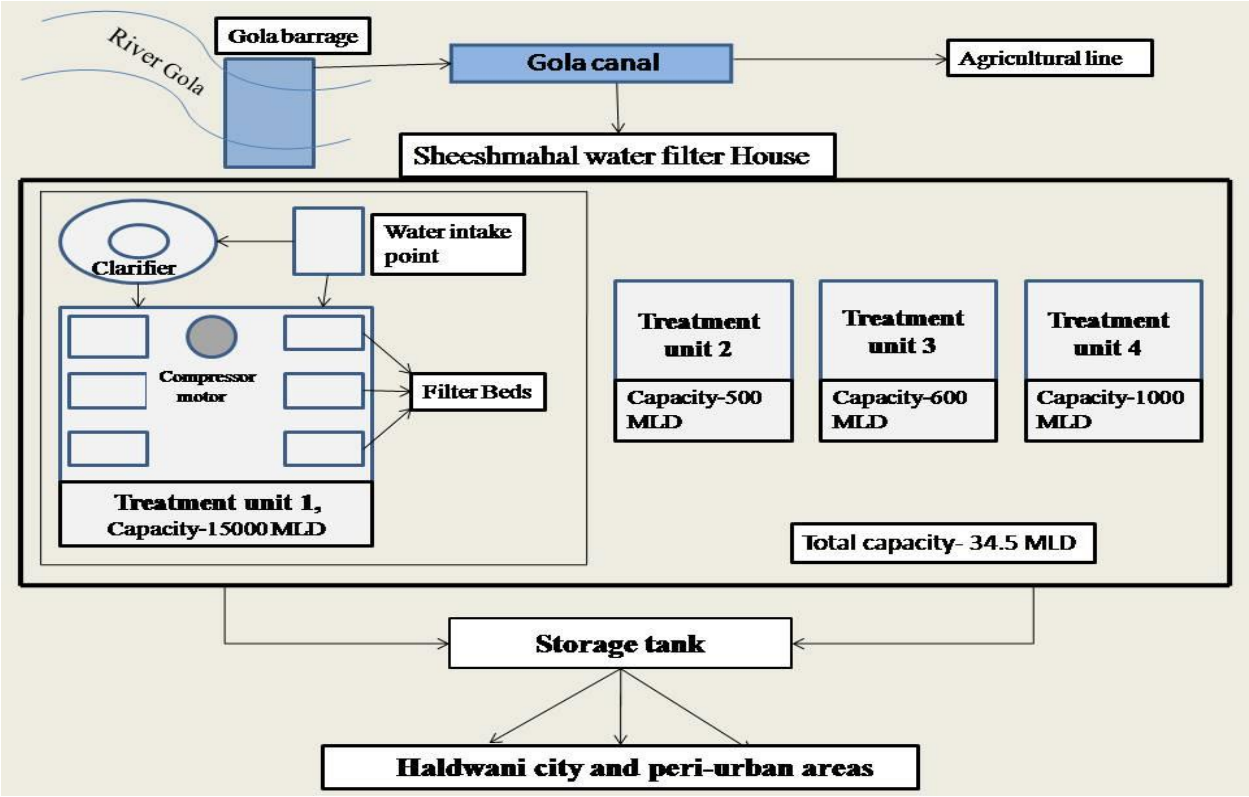


Figure 9.Schematic of Sheeshmahal water filter house.

1000 MLD respectively and the total water capacity of the filter house is 34.5 MLD. The treatment unit 1 is the most oldest among all the treatment units i.e., constructed in the year 1962 while the treatment unit 2 was then constructed at a gap of five years i.e., in the year 1967. The other two treatment units - unit 3 and unit 4 are 25-30 years and 20 years old respectively.

Structure and Treatment:

Water from River Gola gets collected into a water collection tank located besides the water treatment unit 1. About 50% of the water from this collection/intake tank is diverted into a chamber known as **"clarifier"** where the initial water treatment is performed by the mixing of bleaching powder with water (chlorination). Daily about 50 kgs of bleaching powder is used for this purpose after which, the water is then diverted into the unit 1 for the next phase of treatment.

Treatment unit 1:

Inside the water treatment unit1, there is six filter beds arranged in a column of two and row of three which are primarily used for the filtration of water coming from clarifier with the help of media presence on these filter beds. The filter beds are washed once in every four hour to increase the filtration capacity. A compressor motor is located nearby the first two filter beds to provide aeration in the water. This same process of filtration is being performed in all the remaining three treatment units.

Distribution Network: Once done with filtration, water from the treatment units is channeled through pipelines and then gets diverted towards the water storage tank situated near Khandelwal Park from where it is then supplied into the town and the surrounding peri urban areas.

"Poor water supply hits lives in western Himalayan Foothills: A case study of Rajendranagar and Dholakbasti".

Rajendranagar (ward no.2) is one of the administrative wards of Haldwani where conditions are worst as people are struggling for the adequate availability of water to meet their daily needs. On being asked to the ward member- Smt.Rajini, she said that there is no appropriate piped connection in any household in the area or if they have, these connections are of no as they supply very little amount of water to them. She further mention that majority of the Households are dependent on government taps for their water requirements and these taps supplies water only for two hours in the morning and two hours in the evening. During summers and monsoons, Sheeshmahal water lines (extends from Sheeshmahal water treatment plant) gets shut due to the accumulation of silt and mud resulting into water shortage in the area therefore; people go and get water from water tankers. People in Rajendranagar stores water in small vessels or utensils that do not have proper covering on them, increasing the chances of water contamination. Drinking the contaminated water either causes them to fall sick or they suffer from different water borne diseases such as Malaria, Dengue etc.

Since the main concern of the community in this ward is to get enough amount of water to support their livelihood hence, they are least concern about the quality of the water. Related to the quality of the drinking water in the area, Smt.Rajini elaborates about the deteriorating water quality further worsen their living condition. The communities living within this ward have reported the presence of worms and other foreign bodies in their water, but all they can do is simply filtering the water with a cloth. Since, most of the households are not financially good; so they do not even bother to boil the water before drinking. To add onto this the water which they receive is sometimes soapy and have odour prevailing in them. There is no proper sanitation facility in the households or public toilet nearby the ward, hence; people have to defecate in an open field near the river Gola which is the main source of water for the city.

Water supply in Rajendranagar and other wards in Haldwani is operated and maintained by Uttarakhand Jal Sansthan (UJS). The Jal Sansthan and Jal Nigam are building overhead water-storage tanks and tube wells across the city to avail the water facility in the town. Meanwhile, people in Rajendranagar are struggling the battle to clean and adequate water in order to support their livelihood. They have protested quite a time in the office of Jal Sansthan and Jal Nigam explaining the water problems prevailing in their ward but did not get any positive response from their side.

***Dholakbasti**, another administrative ward of Haldwani is located at a distance of 1-2 kilometers from Haldwani railway station. Depending upon different social parameters like caste, income, social status the ward is further divided into two subwards which can be easily eminent in the area itself.*

One of the subward is situated at the walking distance from the main railway station of Haldwani. The entrance of this locality starts with a very narrow passage within a very limited space. About 700 -800 households are living in the area and since it is adjacent to the railway station, people mostly called it as "railway bazaar area".
Most of the families in this subward are either residence by birth or from time duration of 50 to 60 years. Though these families are living here from decades but yet there is not even a single house is found which is made up of solid bricks and cement, which in more technical term known as "pakka house". Houses are mostly built with tents or plastics with mud flooring.

*Majority of people belongs to the Muslim community with an exception of two to three families who are Hindus. Individuals are mostly works on daily basis as wage labors to earn for their livelihood and the occupation in which most of them are involved is locally known as "**dholak ka kaam**". Since the locality is economically weak, households do not have regular accessibility to electricity and sufficient water supply. While interviewing them, most of the people reported that electricity and water are two major barriers they are facing from years. Not even a single household have their own piped connection. They either walk up to a distance of 1km daily or go to Mandi or Bazaar to fetch water or they wait till evening to get water from standpost which are present in a number of three to fulfill the water requirements of 700-800 households. The water from these standpost came for two hours daily.*

Situation is even worse for the children and women in the area because not even a single child has ever been to school to get education. The literacy rate of the locality is nearly zero. On the other hand women are mostly responsible for daily water collection for doing their household chores. They bath once in a week due to the limitation of water. Men and children can go to the Gola River for bathing and sanitation but women are not allowed to go and have bath in open. No household have their own toilet infrastructure and hence people have to go near Gola river to defecate in open which again turned to be a major problem for the women as they are not allowed to go after evening hours. There is no public toilet present in the vicinity of the area which is another bigger challenge for them.

Insight story:

> ***"A one day newly born baby girl was not cleaned up properly due to the lack of water in this subward which shows the depth of situation where people are struggling daily for their survival with no effective support from the Government".***
>
> ***Source: Chirag Ali, Dholakbasti.***

On the other hand there is another area within this ward which is located at a distance of 1-2 km from Haldwani Railway station. Here the scenario related to the economic status, education and other facilities are quite good as compared to the area of railway bazaar. Each household have their own piped connection for water. Syntax tanks are available for the purpose of storing the water along with the sanitation facilities. Economically, this subward is financially good and men and women both are involved in one or any other type of profession.

While asking them about the major barrier they are facing, people reported about the declining quality of water which gets even worst during rainy season. One of the most surprising and good thing here is that some of the women elected by the ward member are actively participated in the management of water supply or looking after of any kind of problem that prevails in the area.

Results and Discussion:

Vulnerability Analysis

Vulnerability refers to the degree to which a system cannot cope with negative impact of climate change, encompassing physical, chemical and social aspects. IPCC characterizes vulnerability as a function of three components i.e. exposure, sensitivity and adaptive capacity. Exposure related to the degree of climate stress upon a particular unit analysis; it may be represented as either long term changes in climatic conditions, or by changes in climatic variability, including the magnitude and frequency of extreme events (IPCC, 2001). Sensitivity is the degree to which the system will be affected by, or responsive to climate stimuli, either positively or negatively. Adaptive capacity refers to the potential or capability of a system to adjust to climate change. The greater the exposure or sensitivity, the greater is the vulnerability, while the greater the adaptive capacity, the lesser is the vulnerability. Vulnerability ranges from -1 to +1, the more positive is the value the less vulnerable is the system, while a negative value represents the more vulnerability of the system. The result of data analysis for all the sub wards within the two main wards for the assessment of vulnerability is given in the table 2. Adaptive capacity is found to be highest for the sub ward 2 of Dholakbasti with a value of 0.608 and it is lowest for the sub ward 1 of the same ward with a minimum value of 0.223. The value of exposure is found to be maximum for sub ward 1 (0.553) and it is minimum for the sub ward 2 (0.500) of Dholakbasti. Sensitivity is found to be more in the sub ward 2 (0.590) of Dholakbasti and it is low in the sub ward 2 (0.466) of Rajendra Nagar. Data analysis of different components of vulnerability assessment from both the wards were done to understand the coalition of the subsequent impacts and to further speculate the degree of vulnerability.

Table 2. Showing the value of Adaptive capacity, Exposure, Sensitivity and Vulnerability in all the 5 sub wards of Rajendra Nagar and Dholakbasti.

Ward Name	Sub wards	Adaptive capacity	Exposure	Sensitivity	Vulnerability
1. Dholakbasti	**Sub ward 1**	**0.223**	**0.553**	**0.497**	**-0.49493418**
	Sub ward 2	**0.608**	**0.500**	**0.590**	**0.036977897**
2. Rajendra Nagar	**SUB ward 1**	**0.332**	**0.550**	**0.533**	**-0.36588519**
	SUB ward 2	**0.365**	**0.550**	**0.466**	**-0.182503931**
	SUB ward 3	**0.597**	**0.550**	**0.513**	**0.151713813**

Fig.10 shows the variability of different socio-economic factors such as house type, occupation and the range of annual income in the two wards of the city. Majority of households from Rajendra nagar are found to abode in semi-pakka houses with no concrete walls and roof. While most of the households from Dholakbasti have an equal number of kachha as well as pakka houses. Wage labor is the most prominent occupation in both the wards whereas the range of annual income falls below one lac and acumen that both the wards are socio-economically weak. Fig.11 shows the analysis of the different sub-components for the accessibility to water in both the wards and the major barriers the community facing in terms of water need. It has been found that more than 50% of the households fetch water for their daily consumption either from “mandi” or “bazaar”. On the contrary, very less number of the households is found to have their own piped connection or a common stand post nearby in the locality as a source of the water.

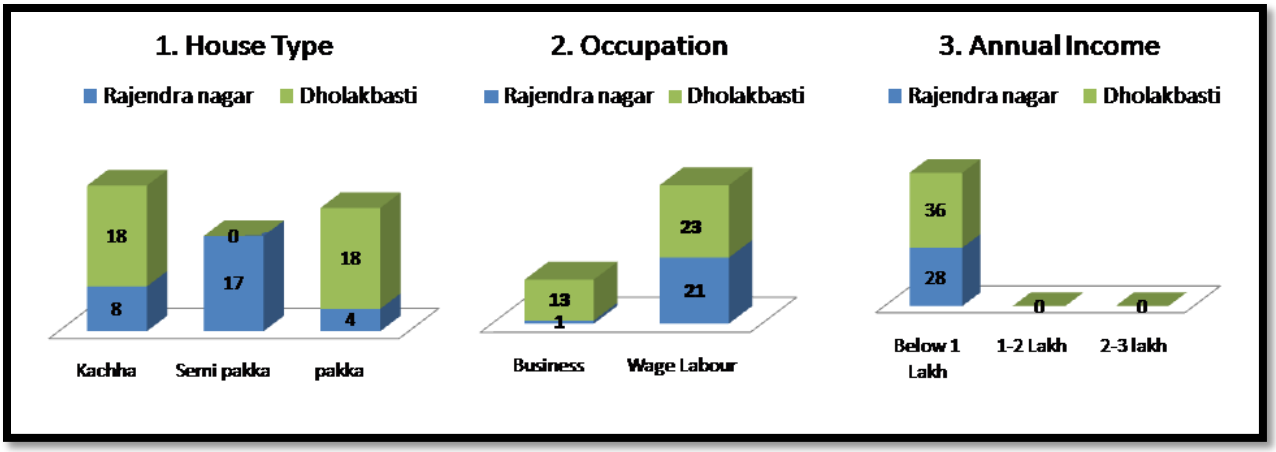


Figure 10.Socio-economic parameters for vulnerability assessment household surveys in Rajendra nagar and Dholakbasti.

Majority of the households in both Rajendra nagar and Dholakbasti stores water in inappropriate and unhygienic containers/vessels and are not equipped with the proper water storage tanks. Erratic water supply and deficiency of own piped connection appears to be the prominent barriers for the community in relation with the accessibility to water.

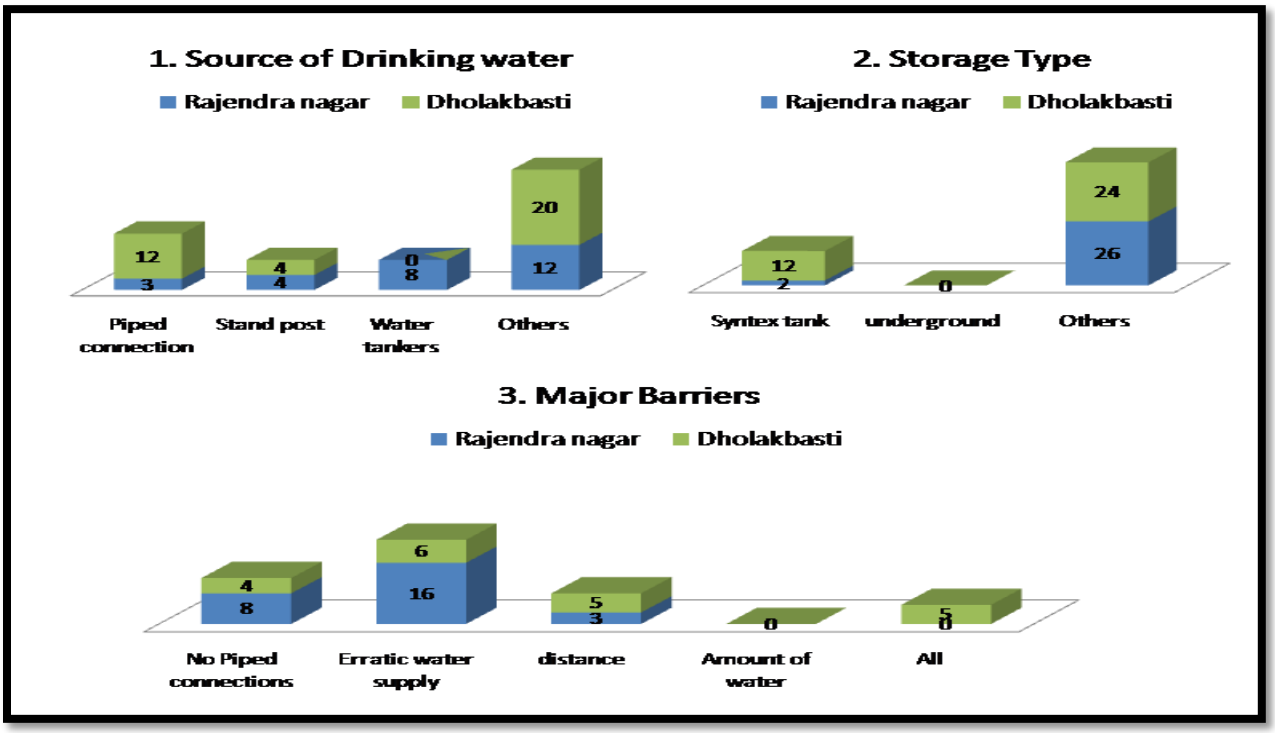


Figure 11.Parameters for accessibility to water for vulnerability assessment household surveys in Rjendra nagar and Dholakbasti.

Fig .12 describes the result of water related health impacts prevailing in both the wards. Most of the households from Rajendra nagar and Dholakbasti are reported to be affected from the water borne health diseases, prevalent among these being typhoid and kidney stone. On the other hand women and children of different age groups are found to be more vulnerable with the diseases reflecting gender differentials which are interwoven with the adverse impact of urban growth and climate change that can be seen in an urban setting.

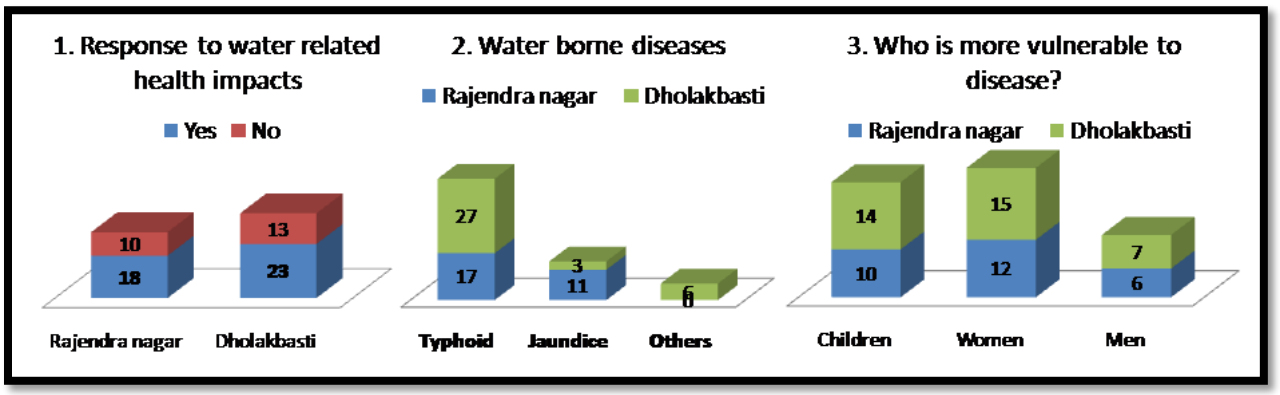


Figure 12. Water borne health impacts in Rajendra nagar and Dholakbasti.

Bacteriological Analysis:

1.Main sources (fig.13)

Of the three main water sources in the city namely: River Gola, sheetlahat spring and tubewells, water sample from river is found to be highly contaminated with feacal coliform count upto 2700/100 mL, water sample from sheetlahat spring reported with the MPN count upto 600/100 mL while the sample taken from the tube well of Rajendra Nagar is found to be free from feacal contamination, on the other hand water sample from the tube well of another ward i.e. Dholakbasti had the fecal coliform count upto 100/100 mL of water sample. In the present study river water is found to be highly contaminated with coliform count and about more than 50% population of the city depends on the water from this river with a total amount of 15.83 MLD. *Rawat et al. (2012)* in their study from River Gola also found that the river water is highly unsatisfactory with a MPN

count upto 1600/100 mL and over a time period of about 7-8 years the MPN count have found to be increased in the river water. *Goel et al. (2007)* in their study from kangra also found the water from spring and river was highly contaminated with faecal coliform count. The most probable reason that has been concluded from the field surveys was that there are many animals and human trespassing along with the open defecation by the community members belonging to Rajendra nagar and Dholakbsti in the area surrounding the river.

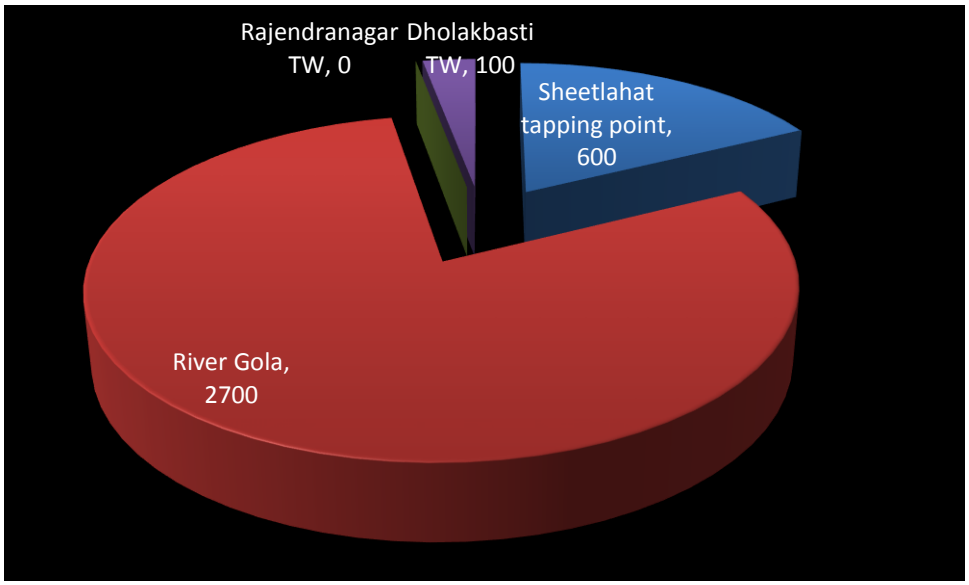


Figure 13.Feacal coliforrm count/100 ml from main water sources.

2. Water treatment plant (fig.14)

At the water filtration point, water sample from River Gola at both the treatment plants reported to be high in contamination from feacal coliform count i.e. 3200/100 ml at sheeshmahal treatment plant and 2700/100 ml at sheeshmahal treatment plant. Since the water samples were taken before the filtration hence again the River water is found to be polluted at the filtration point.

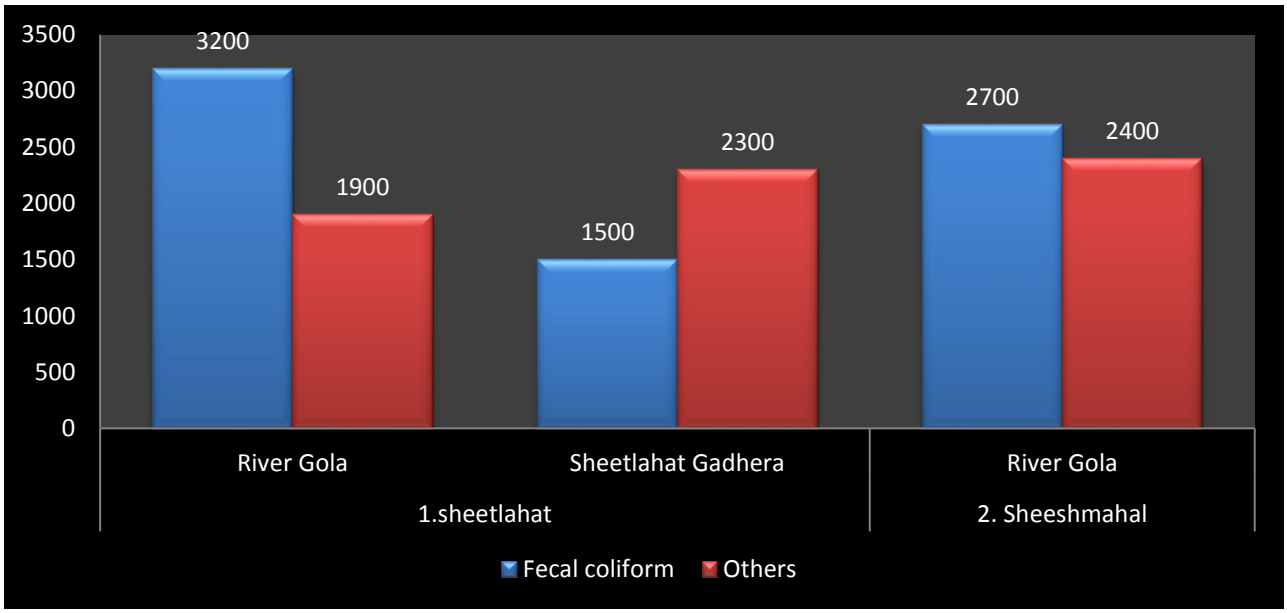


Figure 14. Feacal coliform count/100 ml at the two water treatment plants.

3. Distribution (fig.15)

At the distribution point, water sample from the tap water of Rajendra nagar was found to be more contaminated with the MPN count upto 400/100 mL as compare with the sample from the tap of Dholakbasti with the MPN count upto 100/100 mL. Sample taken from the tube well of Rajendra nagar was detected free from the feacal contamination, on the contrary sample from the tap water of the same ward reported positive with the feacal contamination. The difference in coliform count from source to distribution in Rajendra nagar may occur due to the poor or inappropritae sewer line connection (fig.15). There are numerous political, social and economic issues which underlie the direct causes of poor operations and maintenance of an urban water supply system. These problems result in a substandard water supply, leading to decreases in the quantity of water reaching the consumer, as well as deterioration in the quality of water reaching the consumer *(WHO & UNICEF 2000)*. While the main focus of this study concerns the impacts on water quality and its effects on public health, it must be emphasized that water quantity is highly compromised. Wastage of water through unmetered or illegal household connections, and leakages in pipes and

other valves can lead to massive volumes of water loss. This is by no means an insignificant problem, as this 'unaccounted-for water' in large cities of developing countries is estimated to be greater than 40% of the water volume initially entering the treatment plant *(WHO & UNICEF 2000).*

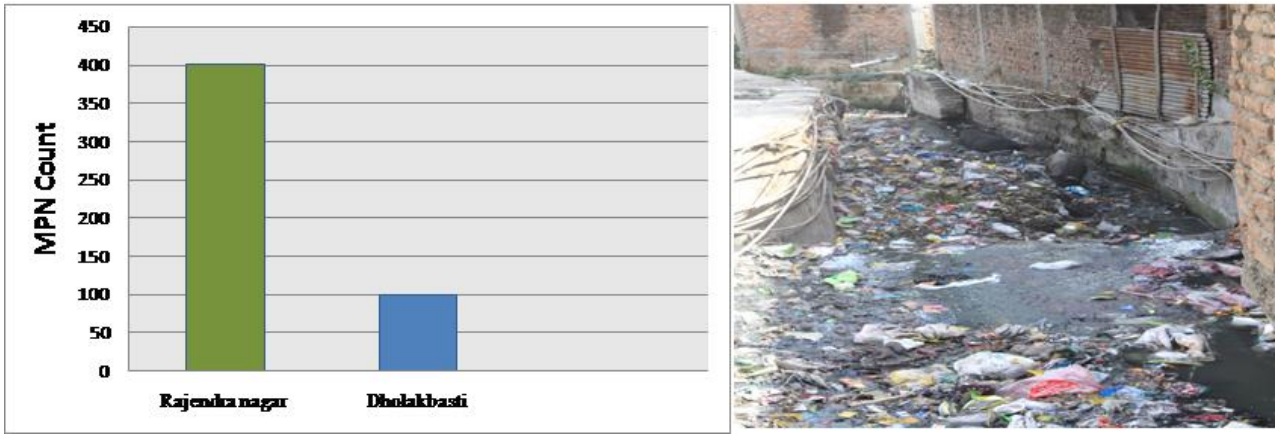


Figure 15.Feacal coliform count/100 ml from government tap water and poor drainage system.

4. Consumption (fig.16)

At consumption level, water from households from Dholakbasti are found to be more contaminated with more MPN count upto 1800/100 mL in sub ward 1 and 2000/100 mL in sub ward 2. However, subward 1, subward 2 and sub ward 3 of Rajendra nagar has been reported with the MPN count upto 1700/100 mL, 0/100 mL and 1400/100 mL respectively.

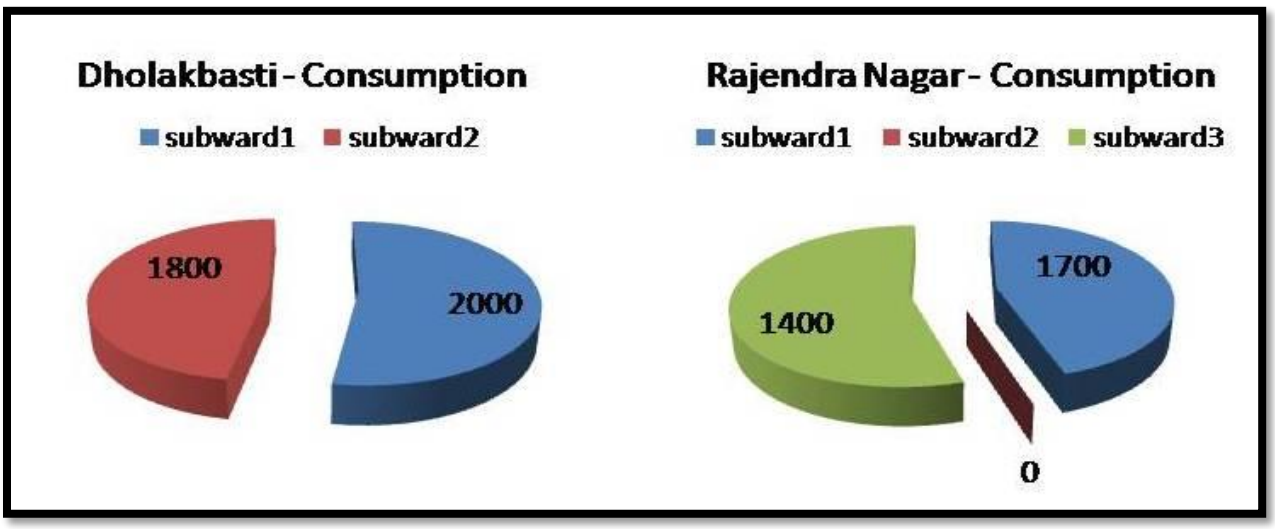


Figure 16. Feacal coliform count/100 ml at comsumption level.

The most probable reason for this contamination and declining water quality at the consumption level could be possibly due to the unhygienic and inappropriate vessels or containers which are used for the purpose of storing the water at households in both the wards (fig.17).

Figure 17. Inappropriate and unhygienic water.storage,

Conclusions and Recommendations

The water samples from (River Gola) within the study area shows an increasing trend in bacteriological contamination with the MPN count upto 2700/100 mL up from 1600/100 mL in last 10 years and so not fit for drinking. On the basis of different parameters like Adaptive capacity, Exposure and Sensitivity – sub ward 1 of Dholakbasti is found to be more vulnerable due to its minimum adaptive capacity while sub ward 2 within the same ward is found to be least vulnerable because it has the highest adaptive capacity. Distribution system deficiencies encompassing “leakage in pipelines” and “inadequate storage” results in decreased quantity as well as quality of water reaching the consumer. Poor water supply operations and maintenance act as a vehicle of transmission for pathogens and contributes significantly to diseases in the community prominently - typhoid and kidney stones. Women and children are found to be more

vulnerable to the water borne diseases reflecting gender differentials which are interwoven with adverse impacts of climate change that can also be observed in an urban setting.

Repair of leaking sewer lines should be given top priority which could be beneficial not only from a water conservation stand point but also to minimize the potential for microbial intrusion into potable water supplies. Installation of Eco-friendly **"Biosand water filters**" could be an effective measure to check and reduce the deteriorating quality of water for example NGOs like- South Asia Pure Water Initiative, Dhan Foundation etc are distributing Biosand Filters in 12,000 villages and have positively impacted more than 100,000 villagers in India. Formation of a **"Water Management Committee"** in each ward consisting entirely of women can be helpful in providing time to time updates related to water issues to the higher authority in the subsequent area.

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