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Review Paper

Water Resources in the Indian Himalayan Region: Issues, Concerns and Best Practices for its Conservation

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ABSTRACT

Water is one of the most plentiful and essential of compounds on the earth which substance composed of the chemical elements hydrogen and oxygen and existing in gaseous, liquid, and solid states. It is considered as one of the most essential natural resource next to air, on which life depends and the system of water resources comprise the snow, glaciers, river, ground water, springs, lakes, and wetlands. The Indian Himalayan Region (IHR) is considered as water tower of Asia which supports welfare of 2 billion people by providing them fresh water. The environmental conditions of this fragile eco-system are deteriorating very fast because of increasing human interference. In the Indian Himalaya, springs are the primary water source and 64% of irrigated areas are fed by springs. Due to factors related to anthropogenic impacts and climate change, springs fed during the monsoon by groundwater or underground aquifers are reported to be drying up and threatening whole ways of life for local communities in most parts of the Indian Himalayan Region. Indian Himalayan Region (IHR) has rich cultural diversity, favorable climatic conditions and attractive scenic beauty. These invaluable qualities made this region significant hotspot for tourism activities that led to increase in road infrastructure, development of the region and increase in the trade as well as upliftment of the economic status of the local community. But due to this, it increased demand of water quantity and quality. Assessment of carrying capacity of popular hill station, water source augmentation and policy interventions in the IHR is the need of present time. To meet-out the future demand of the water, strong water laws should be implemented in the Himalayan region. Conservation and best practices for water resources management should be adopted by all IHR states and union territories.

Introduction

Water is considered as one of the most essential natural resource next to air, on which life depends and the system of water resources comprise the snow, glaciers, river, ground water, springs, lakes, and wetlands. Indian Himalayan Region (IHR) is considered as water tower of Asia, as it is storehouse of snow and ice covered mountains, which plays a crucial role in safeguarding water, food, energy and environmental issues of the inhabitants. IHR is said to be the main source of many rivers, which supports welfare of 2 billion people by providing them fresh water for domestic use, for industries, irrigation purposes, hydropower and sustaining life and it provide many ecosystem services (Provisioning, Supporting, Regulating and Cultural Services), which supports the development of a whole range of cultures, traditions and knowledge systems in the region. At the same time, IHR is also a store house of many hill stations which are popular gateways for holidays mainly because of the aesthetic and natural beauty, situated at higher altitudes with pleasant pollution free climate, peaceful places and being away from city crowds.

The Himalayas and its hill stations are one of the most fragile eco systems in the world and storehouse of countless flora, fauna and glaciers. The environmental conditions of this fragile eco-system are deteriorating very fast because of increasing human interference. This unhealthy relationship between man and nature has been responsible for various ecological disasters in the region. In case of Himachal Pradesh, these environmental degradation and urban environmental problems are on the rise. Increasing population pressure on finite natural resources, deforestation, over grazing, unplanned construction of buildings, networking of roads and large scale modification of natural landscape has caused irreversible damage to the ecology of this Himalayan state. Among the hill stations in the Indian Himalayas, the rate of urbanization has been low in the higher altitudes, but it has been more rapid in the foothills (also called the Siwaliks). In western Indian Himalaya, Srinagar is the largest urban centre, while in the eastern Himalaya, the urban centers of Gangtok, Kalimpong, and Darjeeling have been growing at a very rapid pace. In hill stations, the thrust is always given on increasing the number of visitors and therefore in recent past, supporting infrastructure and activities has increased significantly in excess of regular developmental activities of the respective place. The limiting factors that should have natural control over such development are overlooked, which results in irreversible damage to the local natural resources, ecology and support systems.

Environmental Issues and Concerns

Earliest scholars who studied degrading Himalayan ecology were Duthie (1833) and Lyall (1875) concluded that mismanaged land use, soil erosion and deforestation are major environmental problems in Himalayan states. Increasing population pressure and urban centers in the state have put tremendous pressure on available natural resource. The unplanned developmental process has changed the environmental conditions and has made state disaster prone. Environmental problems of Himachal Pradesh are deep rooted in its geographical setting but these problems have aggravated under the impact of modern developments and climate change. Shimla was planned initially for 25,000 people, now accommodate 1,42,550 people (Census, 2001). As Shimla progressed, it started attracting people from all parts of the country which lead to over crowdedness and congestion. The inflow of tourists and vehicles, traffic jams, unplanned construction of buildings has led to the deterioration of environmental conditions and quality of life in the hilly stations and more or less similar situation arises in other hill stations as well. Major drivers/cocerns in hill stations are as follows:

- Restricted for development and management.
- Topographical difficulty to assess natural resources.
- Rapid urban development and increasing anthropogenic activities
- Problem of increasing local and floating population (visitors and labors)
- Stress on natural resources
- Natural calamities and changing climate
- Rapid land use change
- Solid waste problem and sewage disposal problem
- Poor infrastructure and pressure on existing infrastructure
- Unavailability of comprehensive information of natural resources
- Lack of future prospect while planning water infrastructure

Status of Water Resources in Hill Stations

These hill stations were set up by the colonial British government on ridge-tops, while water sources are deep down in the valleys. Compounding the problem of water shortage are issues such as neglect of traditional water systems like stone spouts and springs, outdated and poorly constructed water distribution systems that get superimposed on traditional water systems, pipe leakages, and poor governance that puts primacy on piped water supply over other time tested and sustainable sources. The fact that mountain towns and cities are also tourist destinations, amounts to additional pressure on water resources, and the water needs of the local population often are not met in pursuit of serving the water requirements of visitors. This sometimes leads to social conflicts. Table-1 shows the water deficiency in some hill stations of India:

Table-1: Gaps between municipal water supply and demand in selected Hill station of India

Hill Stations	Avg. elevation (amsl)	Population (year)	Supply [Million Liters per Day (MLD)]		Demand [Million Liters per Day (MLD)]	Demand met (%) [Million Liters per Day (MLD)]		Years of available water supply/ demand data
			Wet Season	Dry Season		Wet Season	Dry Season	
Darjeeling	2045	1,32,016 (2011)	8.3	2.3	8.6	96.5	26.7	2002
Mussourie	2005	30,118 (2011)	7.67		14.4	53.3		2014
Shimla	2205	1,71,817 (2011)	54.5		64.7	84.2		2012

(Source: Wester et al., 2019)

In hill stations, springs are the primary water source for rural households and also plays important hydrological role in generating stream flow for non-glaciated catchments and in maintaining winter and dry-season flows across the basins. 80% of rural households in Sikkim rely on spring water. Springs also contribute to the base flow of many rivers in the region. In the Indian Himalaya, 64% of irrigated areas are fed by springs. Due to factors related to anthropogenic impacts (such as deforestation, grazing, exploitative land use resulting in soil erosion, etc.) and climate change (e.g., highly variable rainfall), springs fed during the monsoon by groundwater or underground aquifers are reported to be drying up and threatening whole ways of life for local communities in most parts of the mid–hills of the Indian Himalayan Region. They are further impacted by rapid socio-economic growth, demographic changes, and infrastructural developments, such as dams and road building. The water quality in mountain regions of Himalaya is considered to be good and quantity adequate. However, recent reports suggest that urbanization and population growth have been tremendous, which are impacting the land use/cover changes and also endangering the water resources both in quality and quantity. Water quality degradation has significant impacts on human health and ecosystems and is limiting regional development.

Qualitative aspect of water resources in Himachal Pradesh
Physio-chemical analysis of water samples taken from different water sources of famous Kully valley of Himachal Pradesh has been assessed. The results from ex-ante approach infer rise in population of about 15% during 2001–2011, which led to a significant change in land use pattern, microclimate and also increased water demand. Hydrochemistry of the water samples in the study area has indicated that the current status of spring waters is satisfactory for drinking purposes with a few incidences of high NO_3^- which is mostly attributed to contamination from sewage; while F^-, Cl^- and TDS contamination is mainly confined to hot springs. From both ex-ante approach and primary hydrochemical data it can be inferred that springs need to be restored in terms of both quantity and quality. The study concludes that the water resources are vulnerable to anthropogenic interventions and needs treatment prior to drinking. Periodic monitoring of water quality and adopting proper treatment procedures are essential for supplying safe and sustainable water to the community in the Kullu valley, Himachal Pradesh. The Tables are showing different water sources available in the state of Himachal Pradesh:

Table-2: Different water sources in Himachal Pradesh

District	Surface Water	Ground Water	Traditional Sources	Rain Water	Others
Kullu	3392	0	0	0	0
Mandi	3924	833	1483	0	840
Lahul Spiti	290	1	57	0	0
Shimla	3917	233	2518	5	9
Bilaspur	786	827	461	0	0
Kangra	1317	1602	1369	11	466
Hamirpur	485	1057	231	0	1
Solan	1090	344	1215	0	316
Una	123	832	21	1	116
Sirmaur	2249	644	535	0	9
Kinnaur	217	76	24	0	2
Chamba	2433	1717	2598	3	836
Total	**20223**	**8186**	**10512**	**20**	**2595**

Table-3: Popular Lakes in Himachal Pradesh

Sr. No.	Name of Lake	District	Altitude	Area/Hectare
1.	Seruvalsar	Kullu	3301	0.5
2.	Dashair	Kullu	4200	4
3.	Mantalai	Kullu	4160	3
4.	Bhrigu	Kullu	4240	3
5.	Chandertal	Lahul-Spiti	4280	49
6.	Surajtal	Lahul-Spiti	4800	3
7.	Pong Dam	Kangra	430	21712
8.	Dal	Kangra	1840	2
9.	Kareri	Kangra	2960	3.5
10.	Chandernaun	Shimla	3960	1
11.	Rewalsar	Mandi	1320	3
12.	Prashar	Mandi	2600	1
13.	Renuka	Sirmaur	600	15
14.	Mahakali	Chamba	4355	2
15.	Lam Dal Lake	Chamba	3640	5
16.	Mani Mahesh	Chamba	4200	2
17.	Gadhasaru	Chamba	4280	1
18.	Gauri Kund	Chamba	4000	0.5
19.	Khajiar	Chamba	1920	5
20.	Khundi Maral	Chamba	3750	3
21.	Nako	Kinnaur	3604	1

A study in mid hills of Himachal Pradesh has been conducted and assessed the impact of land use change on groundwater quality by taking five dominant land uses viz., traditional agriculture, commercial vegetable farming, orchard, forest and urban in Kullu and Solan district. 60 ground water samples were collected and analyzed for various water quality parameters. Study revealed that the land use changes have exerted significant influence on ground water quality parameters like EC, BOD, COD, chloride, nitrate, sulphate, Ca, Mg, Fe, Pb, Cd and Cr. The BOD, COD Cl, NO_3, SO_4, Ca and Mg concentration in groundwater varied in the order of land use: urban > vegetable > orchard > traditional agriculture > forest. Vegetable and urban land uses have started to adversely influence groundwater quality by exceeding the values of heavy metals over permissible limits. The physico-chemical parameters of water samples collected from Ashwani Khad have been analyzed. The results indicated the values of EC, TDS and TH were above the permissible levels in some of the water samples. Although most of the physico-chemical parameters like Ca^{2+}, Mg^{2+}, SO_4^{2-}, PO_4^{3-}, NO_3, F^-, Cl^- etc, were well within the permissible limits of drinking water quality standards. However, clearly indicate that the water is unfit for drinking purposes. The subsequent study in Aswani khad, Thakur et al. (2017) reported that there were total of 6080 jaundice cases due to water quality problem during December 2015 to March 2016 from areas/localities under SMC wards of Shimla. It was found that Ashwani khad treatment plant was the main source of water supply to the affected wards of Shimla. In addition, the treated sewage effluents released from sewerage treatment plant (STPs) in Malyana and Dhalli were also part of the flow into the natural sources and all this ultimately reaches to the Ashwani Khad. Both studies indicated that water sources were contaminated with sewage waste which is mainly due to urban area Shimla. Mainly, due to increased population, urbanization and increased tourism activities.

Quantitative Qualitative aspect of water resources in the IHR

The Hindu Kush Himalaya (HKH) has bounty cultural diversity, favorable climatic conditions and attractive scenic beauty. These invaluable qualities made this region significant hotspot for tourism activities that led to increase in road infrastructure, development of the region and increase in the trade as well as upliftment of the economic status of the local people. But at the same time there is increase urbanization, change in land use, increased deforestation, loss of biodiversity, which has resulted in increased demand of water quantity and quality. Due these activities urban areas have expanded and replaced with concrete structure, which has reduced infiltration rate leading to decreased groundwater recharge. Whereas, contamination of water sources due to sewage effluent and industrial waste has made quality of potable water unsuitable for use. Table-4 represents the gap between municipal demand and supply of water in selected hill stations of India.

Table-4: Gap between municipal demand and supply of water in selected hill stations

Name of the Urban centres	Population	Water demand [Million Liters per Day (MLD)]	Actual supply [Million Liters per Day (MLD)]	Deficit [Million Liters per Day (MLD)]
Baramula	71434	22.7	7.9	14.8
Shimla	1,69,578	42	20.6	21.4
Mussoorie	30,118	14.5	7.7	6.8
Darjeeling	1,18,805	7	1.9	5.1
Kohima	99,039	10	1.2	8.8

(Source: Singh et al., 2019)

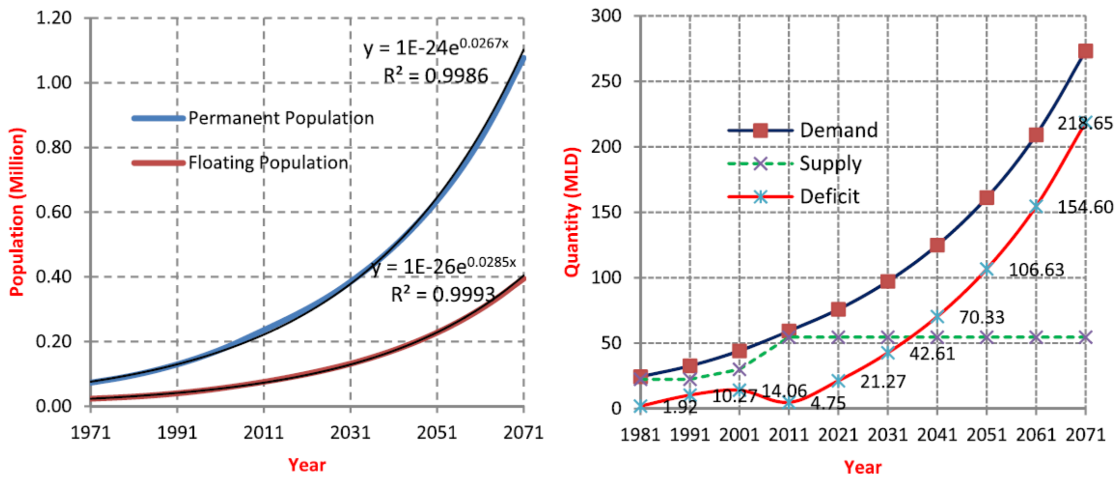
Sharma et al. (2015) carried out resource assessment and strategic planning for improvement of water supply to Shimla city where he identified the issues of water supply in Shimla city and reported that Shimla has permanent and a floating population (2011 Census) of 2,35,970 and 76,000 respectively. Over the period of time, the city grew both geographically and demographically and water demand increased manifold resulting in expansion of the Shimla water supply system into seven independent water supply schemes. Present capacity of existing 7 sources is 54.54 MLD. Further they worked out the population projection and corresponding growing gap between future demand and supply of water in Shimla.

Issues of water supply in Shimla, Himachal Pradesh

SWAT hydrological modeling reveals that Giri water system of Shimla can be converted into a storage based scheme by harnessing cumulative excess inflow volume using small storage dam type rainwater harvesting structure (≈10 m high) that can be built near the existing intake structure of Giri water supply scheme, which is geologically a suitable location (narrow gorge) with rocky formations and affording sufficient storage in the river course itself without causing negative hydrological and environmental impacts. The reach of the river is mountainous and sediment load is not a problem except during flash floods. With average width and depth of storage as 30 x 7.5 m and length of 8 km (1.80 MCM), effective storage of 1.2 MCM can easily be afforded keeping 30% dead storage for sediment load. This storage can meet with the additional water demand especially in May, November and December up to 2031. Keeping in view the small storage (1.2×10^3 km3) as proposed in the dam suggested that the negative hydrological impacts being insignificant can be ignored. There is no reservoir in the watershed (both u/s and d/s of outlet) as such no reservoir simulation is required in the present study. Proposing large storage dam at this site to fulfill requirement beyond 2031, warrants Socio-Economic and Environmental Impact Assessment (EIA) studies besides techno-economical feasibility. Issues of water supply in Shimla are as follows:

- Inadequate water sources: The available water sources in existing watersheds (except Giri watershed) have been tapped to the fullest extent possible.
- Leakage of water: The leakage to the extent of 33% not only causes revenue loss, but is also one of the reasons for inadequate water supply in certain areas.
- Service delivery: Only 70% of the households in the Shimla Planning Area have private water supply pipe connections. The average distribution time is only 45 min characterized by low pressure.
- Cost of production of water: Production cost of water is $0.89 per kilo liters (2014) in comparison with water charges of $0.286 per kL being recovered by the IPH department for bulk supply to the Shimla Municipal Corporation. Municipal Corporation further charges on an average @ $ 0.25 per kL from the consumers.

- Heavy subsidy on water supply: The cost of production of water and water charges from end users in Shimla does not match. The water supply has been highly subsidized to the extent of about 72% for domestic consumers. Existing water tariff structure though conforms to affordability and other social obligations but it does not ensure Economic Efficiency, Cost Recovery and Financial Stability.
- Resource availability: No study has been conducted so far for resource assessment in the existing watersheds, so that additional future water demand could be addressed scientifically.



(a) **(b)**

Fig.1. **(a)** Projected Population and **(b)** Demand - Supply *(Source: Sharma et al., 2015)*

Source augmentation and Policy Interventions

Additional demand of water by 2031 for Shimla city can be meet-out by source augmentation. Source Augmentations for demand satisfaction of Shimla as per rates of year 2014:

- Option-I: Gravitating additional water from upper reach of River Pabbar at a distance of about 138.54 km from Shimla from Chander Nahan having altitude of 4010 m amsl, costing exorbitantly $196.99 million for additional water of 51 MLD. Cost per MLD is $3.86 million. To fulfill the requirement of 2031 (42.61 MLD) proportionate cost is $ 164.58 million.
- Option-II: Additional water from River Satluj (Kol Dam Reservoir) from proposed intake structures at Sunni at a distance of 22 km from Shimla, involving a lift of about 1600 m up to existing storage reservoirs at Ridge and near State Museum. Project cost in this case is $ 63.75 million for additional water of 51 MLD. Cost per MLD is $1.25 million. To fulfill the requirement of 2031 (42.61 MLD) proportionate cost is $ 53.08 million.
- Option-III: Remodeling existing Giri water system built in 2008 into storage based scheme. Capacity of the existing infrastructure like water treatment plant, pumping machinery, pumping mains, main storage etc. has to be enhanced. The project cost has been worked out as $ 32.38 million. Cost per MLD is $ 0.76 million. To fulfill the requirement of 2031 (42.61 MLD) proportionate cost is $ 32.36 million.

The policy intervention is aslo needed for proper water resource management in the IHR, such as:

- Hill station water carrying capacity estimation
- Formulation of water resource development and management plan specifically for hill stations
- Involving dependent local stakeholders in planning and management process
- Compulsory water management pre-conditions for every infrasture development plan
- Demarcation of source area protection zones
- Regulated tourism
- Management plans based on the vulnerability and sensitivity of respective hill stations
- Adoption of global protocols while assessement and continous monitoring.
- Awareness, sensitization and capacity development programmes for stakeholders

Conservation and Best practices for water resources management in hill stations

- Water education for each and everyone
- Practising water harvetsing and making it compulsion for every infrastructure
- Source area protection activities
- Effective management of solid waste
- Proper disposal of sewage water
- Recycling and reuse of water
- Regular monitoring of water quality

- Efficient and optimized demand side management
- Conservation and management Spring, lakes & rivers
- Increasing storage capacity with area specific need and suitability
- Fixing leakages in water distribution system for minimizing water convenice losses
- Increasing forest cover for water retension
- Practising soil and water conservation measures
- Management of unplanned development
- Protecting drainage networks within the hill stations
- Efficient irrgation system and climate smart agriculture
- Conserving and rainforcing tradtional water structures & documenting good water management practices
- Identifying the scope for snow harvesting and artificial galciers
- Selection of indicators for assessing water quantity and quality of hill stations.
- Stringent rules and regulation for water conservation and management

Conclusion

The major inference that emerged out from the qualitative and quantitative aspect of water in hill stations is that both quality and quantity of water in hill stations are in decline mode from above case studies. And the corresponding factors are rapid urbanization and infrastructural development, land use change, problem of sewage disposal, anthropogenic activities, climate change, population (including floating population) pressure, loss of forest and drying of water sources. Therefore, the stress on water resources in hill stations are highly significant and vocal as shown in above case studies and need to be addressed on urgent basis. One of the ways to do that is assessing the carrying capacity of the hill stations to plan the water infrastructure and suggesting policy options for preserving quality and quantity of water in hill station in long run through appropriate conservation and management measures.

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