Impact assessment of spring water on human health in parts of Himalayan region

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Abstract

The purpose of the study is to analyse spring water quality in different regions of the Himalayas and assess its usability as a drinking water source and its impact on human health. The studies conducted by various scientists and researchers in the Himalayan region were understood and analysed based on drinking water standards by WHO and IS10500. The findings from the study show that above 80% of spring water sources in the Himalayan region were fulfilling the drinking water standards and fall under excellent to good condition. The spring water quality in the remaining regions was affected by biological and chemical factors and was not up to the drinking water standards. The spring water quality in the Himalayan region is getting affected by urbanization, anthropogenic factors, and the reactive nature of rocks. Moreover, the topography, geology, hydrogeology, sacred forests, and pristine ecosystems in the Himalayan region are responsible for keeping spring water fresh. The same spring water quality can be preserved using landscape and hydro landscape solutions in the area.

The study is limited to available spring water studies in few Himalayan regions but that gives a fair amount of idea about the whole area and the quality of springs. The study and its findings can be used by scientists, researchers, architects, landscape architects, and other professionals working in this area to understand the importance of spring water and how its quality is beneficial to human health. The study also helps in drawing awareness on how human interventions in the future may affect spring water quality in the Himalayan region.

Keywords: Himalayan spring, spring water quality, health benefits, water standards

1. Introduction

Human is health is dependent upon the quality of water they consume. The human body is 60% of water, it helps in performing various bodily functions. Water carries nutrients and substances to the circulatory system, eliminates wastes and toxins, and helps in lubricating the body.

According to reports, 20% of the world's population consuming unfit water, 32% from protected and remaining from purified and freshwater supplies. The quality of water is dependent on its source and is governed by three parameters, namely, physical (taste, odour, colour, smell), chemical (organic and inorganic composition) and biological (presence of virus, bacteria and protozoa).

The Himalayan spring water is the purest form of water and it is the reason for sustaining life in this region. Temperature, dissolved salts, contained gases, discharge capacity, form, and position of springs are all characteristics of spring water. The spring water, while its flow interacts with different geological structures which impart its water its minerals and other elements. Even a small amount of these soluble matters at the point of emergence can hugely change spring water composition.

As per WHO and IS 10500 standards for drinking water, the pH between 6.5-8.5 is acceptable, the TDS limit is 300ppm for WHO and 500 ppm for IS standard and the hardness should be 200mg/l. Apart from these, the standards also suggest that the number of trace elements, bacteria, viruses, pesticides, fertilizers, and any other chemical or biological agents should be within permissible limits as stated in these standards. The CPCB criteria suggest that the water for drinking should be of A- class quality which is total coliform organism MPN/100ml shall be 50 or less, dissolved oxygen level 6mg/l or more and the biochemical oxygen demand for 5 days at 20degC should be 2mg/l or less.

In regions like Himalayas, high relief and varied geology play an important role in the formation of springs. Every spring in this region is different in terms of its recharge, catchment, discharge, and type. This is governed by the local slope and stratigraphy of hydrogeological layers beneath. These classifications are also responsible for the discharge quantity and water quality of the springs. Various studies conducted on this region show that the spring water obtained from low urbanised areas in Himalayan region (which is mostly the case in this region) are physically and chemically fit, and absence of contamination. More than 80% of the spring sources were found of excellent quality for consumption. The Himalayan zones are ecologically and geologically protected zone which preserves the quality in natural spring water. Various industries in Himalayan region are directly selling this water as mineral water with minimum expenditure on its purification.

However, studies in this region also show that the water quality in few regions is not up to the mark. The water samples collected in Sikkim, Nainital, Dehradun, and others have shown the presence of trace elements and E. coli bacteria beyond safety limits which may result in causing various water-borne diseases.

The factors like urbanization, cutting of forests, and reactive nature of rocks in few regions are the main reasons causing degradation of water quality in these areas. The present study shows the spring water quality in Himalayan regions and landscape solutions that can be implemented to maintain the quality and of spring water in these regions. Further, hydro landscape solutions and their role in maintaining water quality for the sustainable development of spring water have also been discussed.

2. Scope and objectives

The scope of the paper is to assess the impact of Himalayan spring water on human health and how can we maintain the quality of the same using hydro landscape solutions.

The objectives of the paper are as follows:

i. To analyse the formation of different types of springs in the Himalayan region and role of geo hydro chemistry for water quality in this region.
ii. To understand the drinking water quality standards and parameters from IS 10500 and WHO.

iii. To analyse water quality of different areas in Himalayas and its usability as a mineral drinking water based on its physical, chemical and biological composition.

iv. To analyse different factors affecting spring water quality in Himalayan region and related health impacts due to consumption of such water.

v. To understand the importance of landscapes in improving and maintaining the spring water quality and solutions for the same.

vi. Finally, to provide hydro landscape solutions for preserving the quality of springs for human health benefits in Himalayan region.

3. Methodology

There are various studies on the water quality of Himalayan springs. The analysis of spring water quality impact on human health and landscape interventions for improving and sustaining the water quality has not been discussed for the whole Himalayan region.

To meet the objectives of the paper, the following methodology shall be adopted:

i. To understand spring formation and their types along with the role of hydrochemistry in deciding properties of water shall be analysed with the help of the books, articles and literature material pertaining to the subject matter.

ii. Drinkable water quality standards based on its physical properties like pH, hardness, TDS, chemical properties like presence of trace elements, compounds, and biological properties like presence of different bacteria and their permissible limits shall be understood and compared by using IS 10500 and WHO drinking water standards.

iii. Various professionals, researchers, and scientists have conducted studies on the Himalayan region to assess the spring water quality in this area which can be used for understanding the spring water conditions in different regions and the factors affecting the same along with its impact on human health.

iv. After the above studies, the spring water quality shall be analysed using WHO, IS 10500 standards, and the water quality index of available data to classify the regions under excellent, okay, and poor spring water categories. A map will be prepared showing spring water quality demographics using above analysis.

v. The importance of landscape environment along with its use to preserve or improve spring water quality shall be discussed.

vi. Finally, with the help of hydro landscape solutions, we shall be able to determine how we can preserve spring water quality and use it for the health benefits of the individuals.

Literature and data collection

A. Formation of different types of spring in Himalayan region

The spring water which is moving in the ground can be divided into two types:

i. Deep-seated waters

This is the water obtained from absorption from the surface, water which is captured in the sedimentary rocks at their deposition time and water which is rejected during crystallization of igneous rock. The deep-seated water does not move because of the hydrostatic head as it is not connected with any overlying and attaching water body. The flow is in fact due to other influence operative within the earth. (Bryan 1919)

The spring formation is mainly through fault and fissure system in deep seated waters.

Fault springs

In this type of spring, the faulting zones makes favourable conditions for water to come out as the water within the ground is under hydrostatic pressure and move along these faults.

An impermeable rock unit may be brought in contact with an unconfined aquifer due to faulting. (Siddique 2019)

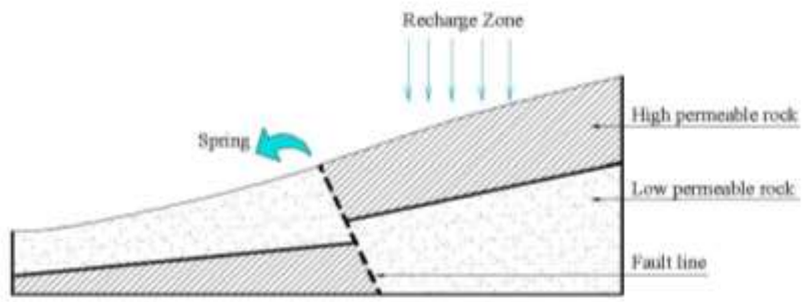

Figure 1 Fault spring

ii. Shallow water

The source of water is mainly through precipitation at the surface and water moves through openings that are super capillary in size. The gravitative pressure causes the water to move through fracture and pore spaces of rocks with a hydrostatic head.

The springs formations are in porous rocks, porous rocks overlying impervious rocks, springs in porous rocks between impervious rocks and impervious rocks.

In the Himalayan region, the following spring types are formed due to shallow water:

Fracture spring:

Fracture springs form in permeable fracture zones occurring in low permeability rocks. The water within the ground moves mainly through the fracture which taps both shallow and deep aquifers. The intersection of these fractures with the land surface helps in forming springs.

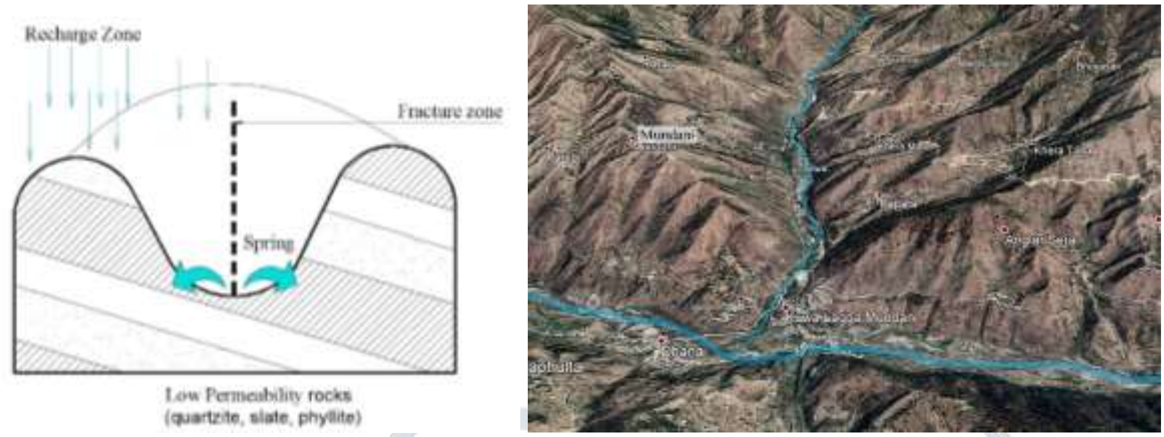

Figure 2 fault spring in Mundani region Uttarakhand

Contact spring

The zones where permeable rock lies over low permeability rock forms contact springs in lithological contact zones and are associated Such springs are usually associated with perched aquifers in mountains.

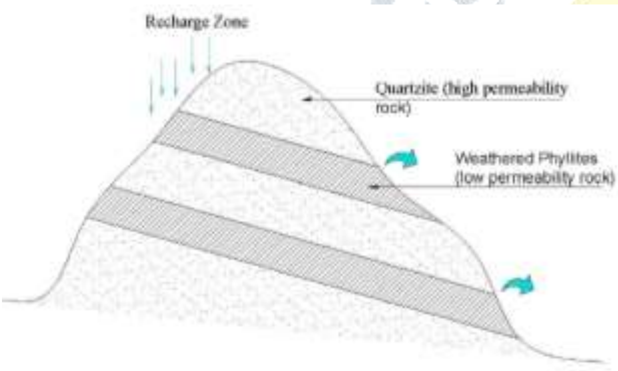

Figure 3 Contact spring

Karst springs

Limestone, gypsum, and dolomite are soft and reactive stones that are responsible for forming karst topography. This dissolving nature of rocks leads to the formation of sinkholes and caves. The water enters sinkholes and exits through fissures in the karst mass.

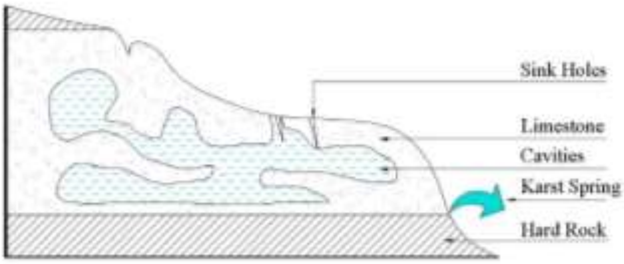

Figure 4 Karst spring

Depression springs

The water in these springs flows through pore spaces in loose sediments due to gravity (also known as gravity depression springs) and faces a change in slope at the ridge base when topography intersects the water table. These are the most common springs in Himalayan region which form at cliffs and along the hillside.

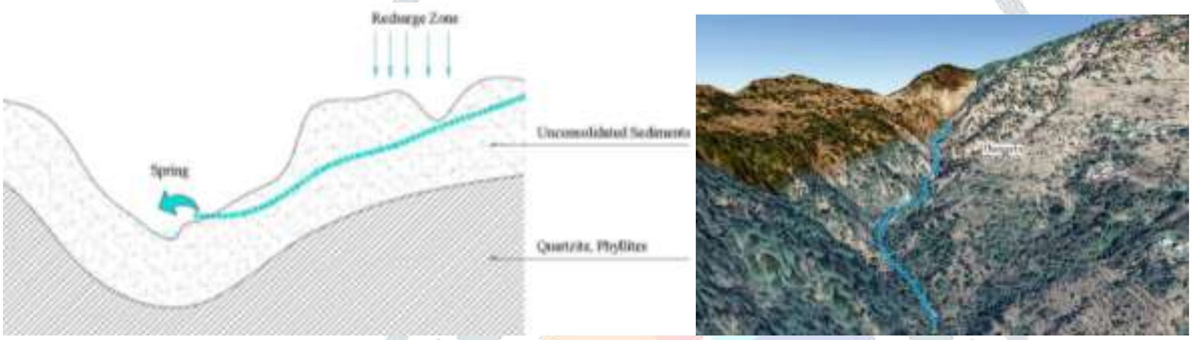

Figure 5 Depression spring in Dangala region

B. Reactive rocks in Himalayan region

Table 1 Rocks in Himalayan region and their reactive nature (Source: Central Groundwater report in Himalayan region)

Region	**Basic geology of the area**	**Reactive rocks**
Jammu and Kashmir	calcareous Laminae, Agglomerate slates, Sirban limestone, Sandstone, mudstone, Shale, Granite, Bhaderwah Slates; porphyritic granite	Sirban limestone, calcareous laminae Slate- partially reactive
Himachal Pradesh	Dark grey carbonaceous slates, siltstones, Granite, schist, Phyllites, Quartzites, limestone, Shale, dolomite,	Limestone, dolomite

	Dalhousie / Kullu granites, gneisses, Clay, sandstones, Siltstone, amphibolite, migmatite	
Uttarakhand	gneisses, migmatites, crystalline schist, shale, slate, phyllite, compact sandstone, limestone, dolomite Granite, quartzite	Dolomite
Sikkim	shale, sandstone, quartzite, dolomite, Migmatite gneisses, Augen gneiss, Amphibolite, Phyllite, Slates, granite	Dolomite

C. Drinking water quality standards as per IS 10500 and WHO

Table 2 Drinking water standards (Source: (S 2012) (WHO 2008))

s.no	Characteristic	Acceptable limit as per IS10500	WHO standards
1.	pH	6.5-8.5	6.5-8.5
2.	TDS	500ppm	300ppm
3.	Aluminium mg/L	0.03mg/l	0.1-0.2
4.	Ammonia mg/L	0.5 mg/l	1.5 mg/l
5.	Barium mg/L	0.7 mg/l	1.3mg/l
6.	Boron	0.5 mg/l	2.4 mg/l
7.	Calcium	75 mg/l	Not specified
8.	Chloramines	4.0 mg/l	Not specified
9.	Chloride	250 mg/l	Not specified
10.	Copper	0.05 mg/l	2 mg/l
11.	Fluoride	1.0 mg/l	1.5 mg/l
12.	Free residual chlorine	0.2 mg/l	Not specified
13.	Iron	0.3 mg/l	Not specified
14.	Magnesium	30 mg/l	Not specified
15.	Manganese	0.1 mg/l	Not specified
16.	Nitrate	45 mg/l	50 mg/l
17.	Selenium	0.01 mg/l	0.04 mg/l
18.	Silver	0.1 mg/l	Not specified

19.	Sulphate	200 mg/l	Not specified
20.	Sulphide	0.05 mg/l	Not specified
21.	Alkalinity as calcium carbonate	200 mg/l	Not specified
22.	Hardness CaCO3	200 mg/l	Not specified
23.	Zinc	5 mg/l	Not specified
24.	Cadmium	0.003 mg/l	0.003 mg/l
25.	Cyanide	0.05 mg/l	Not specified
26.	Lead	0.01 mg/l	0.01 mg/l
27.	Mercury	0.001 mg/l	0.006 mg/l
28.	Molybdenum	0.07 mg/l	Not specified
29.	Nickel	0.02 mg/l	0.07 mg/l
30.	Arsenic	0.01 mg/l	0.01mg/l

D. Himalayan Spring water studies by various researchers and their results

Study	Results
(Tiwari 2020)	• Himalayan regions have more than 600geothermal springs with different temperature and chemical properties. • The study shows that the Garhwal region faces CO2 discharge in water obtained from metamorphic decarbonation of carbonate rocks in the Himalayan core. • the water shows magmatism and oxidation of graphite. • A high concentration of Cl- and Na+
(Jaspal Singh Chauhan 2020)	• Water quality assessment of a village in Uttarakhand. • The water quality of natural springs was falling under excellent condition but the supplied water samples. • Presence of coliform bacteria due to the unmanaged sewer. • 78% of the population suffering from water-borne diseases.
(Dhirendra Kumar Tripathi 2015)	• Study on 10 spring samples of Dehradun • The water samples were within permissible limits, except for few. Although, the water from all samples was found fit for consumption.
(Devendra Kumar Chauhan 2019)	• High iron content was found in water samples which is affecting water quality • This type of water is not suitable for storing due to its reactive nature

	• The water quality may also promote breeding of bacteria.
(Lodhi 2020)	• Water quality assessment on 7 spring samples from upper Subansiri Arunachal Pradesh • All samples were in excellent condition for human consumption. • Excessive agricultural practices near spring sources leading to the deposition of salt and fertilizers in the water sample. • Weathering activity in summer shows high mineral deposition in water sample.
(Ghulam Jeelani 2018)	• Spring hydrochemistry in Kashmir region is dominated by weathering of carbonate rocks (Karst system). • The water in this system is very volatile and capable of dissolving host rock in most seasons. • The water in Karst systems was found appropriate for drinking. Except for the summer monsoon season, the concentration of NO3 and coliform bacteria and streptococci bacteria increased.
(Dr. G.C.S. Negi 2007)	• The study conducted in the western Himalayas on springs shows the water quality of the 12 springs namely, Teendhara, Bidakot, Karas, Kothar, Bhaktiyana, Gulabrai, Kamera, Chatwapipal, Bhatoli, Maithana, Batula, and Joshimath. • The water quality was found in safe limits as per BIS water quality parameters. • The TDS in Bhaktiyana (364mg/L) and Kothar (338mg/L) springs were beyond safety limits maybe because the settlement rates are high (62.7% and 62.6% respectively) and low forest covers in these regions. • Bacteria were found in all water samples whereas coliform was absent in water samples from Bidakot, Gulabri, Kamera, and Joshimath springs. • *Escherichia coli* was not present in any of these springs sample.
(Ajay Kumar Taloor 2020)	• Water samples from 60 spring sources in Basantar watershed in the Jammu Himalaya region. • The water quality samples in 45%springs were in the excellent category, 50% in the good category, and 5% in poor category. • No sample was extremely unfit for consumption.
(Showkat Ahmad lone 2020)	• Study conducted in South Kashmir region • water quality in this region has good potential for drinking. • The water samples dominated CA-Mg-HCO3.

(C.K. Jain 2010)	• Study conducted in Nainital area • Springwater samples are not as per standards in most of the parameters like alkalinity, hardness. • The bacteriological analysis showed contamination in spring water sources.
(Nandini Thakur 2018)	• Water quality analysis in Kullu region. • Water samples showed promising quality for drinking purposes. • Few samples showed a higher concentration of NO3- due to sewage contamination. • Fl-, Cl- and TDS contamination in hot springs. • Needs treatment before consumption.
(Ashish Kumar Singh 2019)	• The study conducted in Sikkim region. • Microbial parameters in all water samples were beyond safety limits. • Traces of heavy metals were found above standard limits prescribed by WHO.
(Joshi 2008)	• Water samples from 8 springs in Almora- Binsar • area under forest cover with sparse population had lower EC, cation -anion composition and is safe for drinking • the springs from irrigated land and higher population density had higher EC, high quantity of NO3- , low DO which makes it unsafe for drinking. • The degraded forest springs had high E. coli which makes these areas vulnerable to water-borne diseases. • The presence of *E. coli* colony formation was observed more in rainy season followed by summer.

4. Analysis and discussion

From the above studies we can observe that the spring water quality of the studied regions was mainly dependent on the following factors:

i. Hydrogeology and hydrochemistry: The different types of rock formation, spring types, stratigraphy, reactive nature of rocks along with the duration of interaction with water decides the physical and chemical properties composition of the spring water. For example, in geothermal springs (Tiwari 2020), water samples had higher concentrations of Cl- and Na+ which signifies the deeper sources of water. In karst system, high concentration of calcium and magnesium was observed due to water reacting with weathered carbonate rocks (Ghulam Jeelani 2018).

ii. Temperature and climate: Different studies to prove that spring water quality parameters showed alteration in their concentration in different seasons. High E. coli. Concentration was observed in the Sikkim region during the monsoon season (Ashish Kumar Singh 2019). Also, with the increase in temperature, the dissolving capacity of water increases which can be the reason for the change in concentration of compounds in water.

iii. Impact of forest cover and lands: As per the studies, the forest cover provided better recharging grounds for spring water than any other man-made interventions like trenches, recharging ponds, terracing, etc.

iv. Urbanization and anthropogenic activities: The spring water quality was disturbed in a few of the studied regions due to urban factors. Also, anthropogenic activities like mining, industrialization, improper sewage disposal have disturbed the water quality in many regions.

The water quality assessment of the springs in the Himalayan region based on its physical, chemical, and biological compositions shows that more than 90% of the spring water resources in the Himalayan region are in excellent to good condition and fit for drinking which requires minimum or no purification. The values also satisfy WHO and BIS standards of safe drinking water. This can be attributed to the fact that the topography, hydrogeology, and pristine ecosystems of the Himalayan regions make this water fresh and fit for consumption.

The spring water quality in these regions and their characteristics can be compared with mineral water. Moreover, the water from these sources can be used to cure several chronic diseases due to its mineral properties (Sara Quatrini 2017). The health resorts in Uttarakhand are already providing cures with the Himalayan spring water and the therapies mainly involve drinking and bathing cure.

On the other hand, the poor water quality in the remaining zones is due to urbanization factors and anthropogenic activities. In some of the cases, heavy metal compositions and trace elements were observed in higher concentrations due to reactive nature of rocks. The natural factors unfitting the water quality is very less compared to human interventions.

The spring water sample in the Sikkim region showed a higher concentration of cadmium, mercury, chromium, and selenium. These can possess a serious threat to the health of people drinking this water. The consumption of these toxic elements like Cd and As may lead to cancer, kidney damage, disturb bone metabolism, deform reproductive tract, and heart diseases. Mercury passed into the blood may lead to kidney, liver damage and impact on the cardiovascular system. The presence of microbial bacteria was also alarming and hence the reports show considerable growth of water-borne diseases in this region.

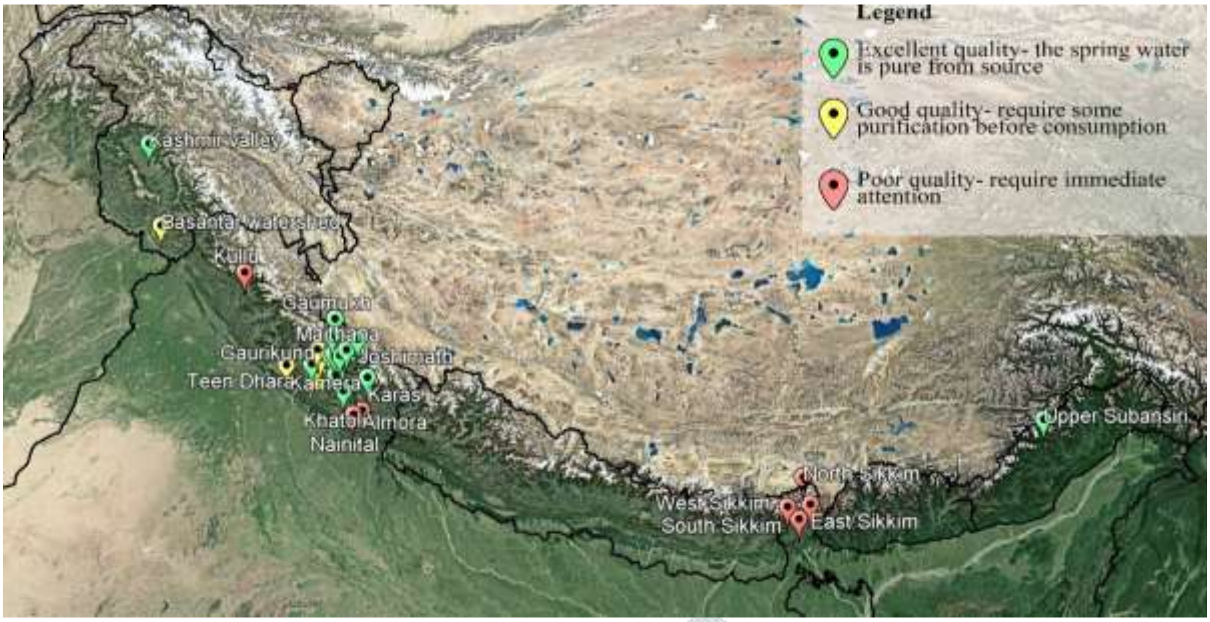

Figure 6 Spring water quality demographics in Himalayan region

Role of landscapes in maintaining the spring water quality and health of the individuals

The natural landscapes of the Himalayan region are the reason for magnificent spring water quality here.

The study conducted by (Purna Jana 2018)shows how the sacred grove forest in the Garhwal region of the Himalayas are important for maintaining the water quality here. The water quality samples from these oak and deodar forests were up to the WHO standards.

Native trees have great hydrogeological value to the place. Their floor covered with litter and humus provides better ground for water purification and infiltration to the ground better than scrubs, grasslands, and rocky terrain.

In the Himalayan region, many such grove landscapes and native trees helps in sustaining the spring water quality and there is a need to preserve them. Any anthropogenic activities disturbing the sacred forests should be restricted.

The urban factors and farmlands are another topic of concern when we talk about spring water quality. The rainfall water which carries pollutants from urban lands and the residuals of chemical and fertilizers from agricultural lands gets deposited into water bodies and also pollutes the surface water. The water from these sources should be first treated on-site by recycling and then can be reused for irrigation purposes.

As we saw in the case of Nainital how sewage is disturbing the water quality in the area. Provisions should be made for effectively dealing with the sewage or any other sources of pollution which may affect spring water quality.

Not only trees but certain grasses also help in purifying water. The wetlands and rootzone systems can be used for improving the water quality by removing pollutants from surface water by:

i. Trapping the sediments

ii. Removing the nutrient

iii. Chemical detoxification

Almost 90% of the sediment load is cleaned when water passes through wetlands. Along with this, the settling of sediments carrying heavy metals while passing through wetlands improves water quality. The harmful nutrients like nitrogen, phosphorus from sewage, septic systems, fertilizers, etc when pass through wetlands systems are taken up and break into less harmful chemical forms by wetland plants. Also, these nutrients get recycled along with the wetland plants. Sometimes, wetlands with special plants are specifically built for these purposes. Freshwater wetlands can also be used where water enters the spring for recharging them. (dec.vermont n.d.)

Hydro- landscape solutions for maintaining spring water quality

Since springs are generally fed by shallow seated water in the Himalayan regions, they are more likely to be contaminated on the surface. Therefore, protecting the springs from surface contamination is important during all processes of spring development. The hydro landscape solutions are context-based and can be implemented by understanding the site conditions like type of springs, direction of waterflow, hydrogeological features etc.

The spring water can be collected from the upstream direction as water in the lower stream direction is more likely to get polluted. The construction of rock bed to form an intercepting reservoir or collecting through trench and then connecting them with pipe to direct the spring water to the spring box. It is important to remove any source of pollution or surface water from entering spring box.

5. Conclusion

The complex topography, geology, hydrogeology, and lithostructural units in the Himalayan region is the reason for the formation of different types of springs in the region The depth of water in springs, its interaction with different rocks and duration of interaction all together determine the spring water characteristics.

The spring water quality in the Himalayan region was mainly affected by reactive nature of rocks, forest cover, climate, temperature, urbanization, and anthropogenic activities. Out of these factors, we can only preserve the forest cover, control urbanization factors and anthropogenic factors from affecting the spring water quality from deteriorating.

The spring water samples collected by various researchers and scientists in this region when compared with WHO and BIS standards showed promising results. Above 80% of the studied spring water sources were found in excellent to good condition for drinking water purposes and hence can be used directly from the source without any further purification or minimum purification. This spring water can be used as mineral water for the treatment of various chronic diseases in health resorts or yoga ashram environments.

On the other hand, the water quality in the remaining areas was not up to the drinking water standards by WHO and BIS and hence may lead to serious health conditions and chronic diseases. However, current cases of health implications caused by drinking poor quality spring water were not mentioned in any of the studied areas.

Through this study, we were able to determine the landscape environments and how it is effective in controlling the water quality in the Himalayan region. The indigenous species and sacred grooves play a dominant role in conserving the water quality and hence the preservation of these forests and mass planting of native trees is important. Furthermore, the water contamination from urban areas and farmlands can be controlled and the water quality can be improved by onsite treating of the water containing toxins and chemical fertilizers using wetland systems.

Finally, with the help of hydro landscape solutions discussed we can provide and preserve the water quality for the health benefits of the individuals depending on it.

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