Water quality and quantity analysis in Sikkim, North Eastern Himalaya

Archana Tiwari

Sikkim is known for its substantial water resources. However, due to rapid growth in population and industry, water scarcity is increasing day by day adding stress on these resources, both quantitatively and qualitatively. A comparative field study performed during January 2011, of available water in Namchi, Gangtok and Singtam areas of Sikkim is presented here. The study illustrates the quality and quantity of water, and their time-dependent variations during the year. Data on pH and coliform were used to assess quality, whereas questionnaire modules were used to find out the abundance of water for domestic use on various scales. The findings regarding water management on the local scale reveal the degree of awareness and the measures taken for water conservation, health and safety. The survey also focuses on the large number of hydel power projects commissioned in the state.

Keywords: Hydel power projects, microbial activity, pH value, qualitative and quantitative analysis, water management.

WATER is a probe to detect the occurrence of climate change, especially in mountainous regions. Melting glaciers supply water to rivers, springs and lakes. They are the major water resources for irrigation, not only in the mountains but also in the plains. The amount of water flow depends extensively on weather conditions. For instance, winter is often a water-scarce season in the mountains compared to monsoon or summer.

The variation in water run-off may result in either too much water or no water[1] and therefore increases the vulnerability of livelihoods in the mountains[2]. This also poses risks to human lives through water-borne diseases and affects infrastructure. For example, the increased frequency of landslides and flash floods, and reduced water flow in the dry seasons would make the functioning of various hydel power plants difficult, thereby constraining their capacity to meet the energy requirements; also, tourism could be adversely affected due to recurring natural hazards[3,4].

Sikkim, a northeastern state in the lap of the Eastern Himalaya, has cardinal importance not only because it shares boundaries with three nations, viz. Nepal, Bhutan and China, but also due to its immense biodiversity. This mountainous state has its own glory and gloom when it comes to water. On the one hand, waterfalls, springs, rivers and religious lakes (for e.g., Khecheopalri, Gurudongmar, Changu lakes, etc.) attract tourists and revenue, and on the other, recurring landslides, blocked roadways, water contamination and scarcity mar the prospects of its glory. In spite of the presence of contaminants, the quality of water remains better than that in the lowlands of India[5].

The water run-off in the state flows through various geological structures such as joints, fractured and weathered zones in the phyllite, schist, gneisses and quartzite rocks[6]. Rainfall remains the principal mode of recharge of surface water[7]. Due to mountainous slopes, most of the precipitation causes surface run-off resulting in streams, springs and *kholas*[8]. They are further tapped through pipelines and distributed by the gravity method for domestic use. As the major portion of water supplied to the locals is in continuous contact with the surface, it further increases the risk of microbial presence in the water[9] and elemental contamination from country rocks.

This article presents an overview of the water resources in these mountains and their management in the East and South districts of Sikkim (Figure 1). The study performed in January 2011 reveals the quality and quantity of water resources, their management on a local scale, the hydel power projects and the perspectives of the people.

Methodology

Thirty water samples collected from various regions were stored in airtight containers (Figure 2). The pH values were measured immediately after collecting the samples using a portable pHep pocket-sized pH meter (Hanna Instruments) with an accuracy of ± 0.1.

The existence of coliforms was tested by monitoring their growth in laboratory. The presence of these coli-

Archana Tiwari is in the Department of Physical Sciences, Sikkim University, Gangtok 737 102, India.
e-mail: archana.tiwari.ox@gmail.com

forms is an indication that the water has been in contact with the surface and may contain disease-causing organisms. Using the conventional most probable number (MPN) test, the presence or absence of microorganisms was confirmed. The samples were inoculated with lactose broth (peptone 5.0 g, meat (beef) extract 3.0 g and lactose 5.0 g in 1 litre of distilled water) at 37°C for 48 h. The presence of gas bubbles was indicative of the presence of microbes.

A total of 570 household surveys were carried out in Namchi (250 surveys), Gangtok (250 surveys) and Singtam (70 surveys) including their neighbourhoods, and the results were analysed.

Results and discussion

Water quality: pH values and microbial activities

It was observed that the water run-off and hence water supply to the public in Sikkim is uneven. If East Sikkim receives plenty of water throughout the year, the South district suffers from huge shortages several times. Based on the water demand and supply from government or private organizations, field surveys were done primarily in two major cities, namely Namchi in South Sikkim and Gangtok in East Sikkim. Many villages in the vicinity of Namchi have extreme water shortages throughout the year.

The water quality in Sikkim varies from excellent to highly poor depending upon the seasons. The present survey reveals that 99% of the respondents are satisfied with the water quality available on the local scale. However, the water run-off (during monsoon) in the springs and rivers contains mud and pollutants. Further, the frequent landslides and flash floods cause water contamination in the supply lines. This causes massive disruption in the water supply to households in addition to inviting the threat of several water-borne diseases. The survey in hospitals reveals that about 29% of respondents suffered from water-borne diseases during the monsoon season in 2010. This number is relatively low, as a large number of people in the region prefer boiling the water before drinking. Later, it was confirmed that boiling the water samples not only kills the microbes present, but also lowers the basicity of water to an acceptable level.

On the contrary, the run-off during winter is extremely slow and less in quantity and, inevitably better in quality. This is why the survey was preferably carried out in winter. Different water samples were collected in January 2011, when the average temperature was 10°C. The study was first performed in Namchi and its neighbourhood, in particular, the water-scarce villages like Tinjhir, Boomtar, Kamrang, Assangthang and Solophok. A continuous basicity with average pH value of 7.5 ± 0.1 was observed. Also, most of the samples showed an affirmative coliform test with the exception of the one procured from Solophok (Table 1). On site observation, it was found that a Shiva monument was under construction here, and the water tank onsite was frequently debased by the use of paint and slaked lime. This accounts for the high pH value and absence of microbial activity in the water.

The study on water quality was also performed in Gangtok and its neighbourhood, viz. Singtam, Tadong, Deorali, Sichey, Selep, Ranipool and Rumtek. The average pH value was found to be 8.4 ± 0.1. Except for the chlorinated water at the Selep water treatment plant, the water samples were found to have microbial presence. In Selep, chlorination is primarily used for disinfection of the collected water. However, it is known that drinking chlorinated water on a long term may lead to cancer, mutations and other adverse health outcomes[10,11]. Therefore, promising alternatives are required such as ultraviolet, ozone or ultrasonic disinfection for massive scales[10,12].

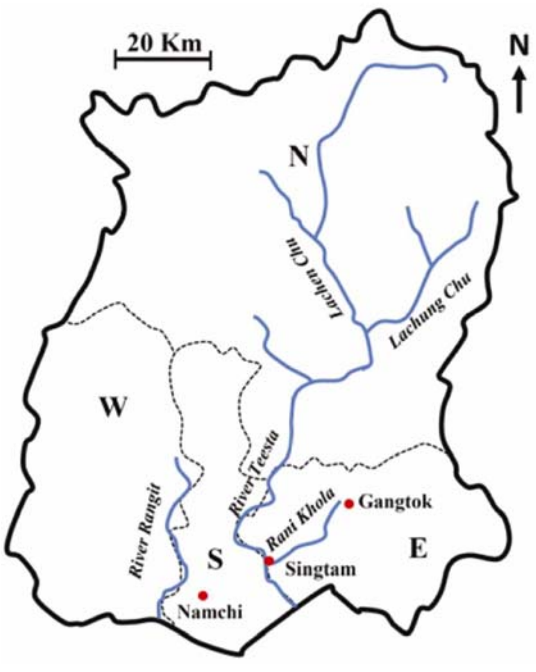

Figure 1. Geological map of Sikkim. The black curve shows the state boundary, whereas the black dashed curve shows the district boundaries within Sikkim (N for north, E for east, S for south and W for west districts respectively). The blue curve shows the major rivers.

Figure 2. Water samples collected from Namchi, Gangtok and Singtam and their neighbourhoods.

Table 1. pH value and microbial activity in various samples collected from Namchi, Gangtok and their neighbourhoods

City/town/village	Point of sample collection	pH value	Microbial activity
Assangthang village, Namchi, South Sikkim	Micro Kunwa	7.4	Present
	Chota Kunwa	6.7	Present
	Bada Kunwa	8.3	Present
	Bhutia Kunwa	7.5	Present
Namchi, South Sikkim	PHE raw	7.8	Present
	PHE treated	7.9	Present
	Tinjhir Dhara	7.7	Present
Kamrang village, Namchi, South Sikkim	Kamrang Govt College	7.9	Present
	Kamrang Kunwa	7.6	Present
	Chinzey Wakchu Khola	8.1	Present
Solophok, Namchi, South Sikkim	Chardham storage tank	8.5	Present
	Chardham storage tank at Shiva monument	9.5	Absent
Singtam, East Sikkim	Rolep Dhara	8.2	Present
Ranipool, Gangtok, East Sikkim	Ranikhola	8.4	Present
	Sewerage water after treatment	8.2	Present
WTP, Selep, Gangtok, East Sikkim	Inlet water	8.1	Present
	Chlorinated water	10.6	Absent
	Final staged water	8.1	Present
Rumtek, Gangtok, East Sikkim	Simsar	8.5	Present
	Natural source, Sirwaw	8.0	Present

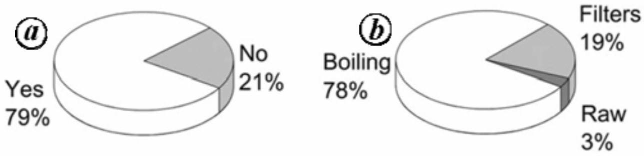

Figure 3. ***a***, Response on the visible changes in the water supplied during monsoons. ***b***, Response to contamination: measures taken on the local scale to purify drinking water.

It was observed that the basicity of water in Gangtok is temporary. The pH value comes down after boiling to an average of 7.9 ± 0.1. This reveals that people who boil water before drinking are not only killing the microbes present, but are also bringing the pH value to an acceptable level[13,14]. However, many respondents were unaware of these facts. Their major concern was to drink boiled or warm water as the water, in general, is cold and unbearable for drinking in its raw form (Figure 3).

Water management

During the field survey, the modes and mechanisms of water storage, treatment and its distribution to the public were also analysed. The chief sources of information are the local public, Water Security and Public Health Engineering Department, and Rural Management and Development Department.

It was observed that Namchi and its neighbourhood had expanded considerably in the last 30 years since the inception of the water supply tanks and the commissioned source at Bermelly. The present source offers 70 litres of water per capita per day during summer and about 50 litres per capita per day in winter. This is the minimum amount of water supply in other cities in Sikkim[15]. The existing infrastructure, with only one source line, is inadequate to serve local demands; it calls for a parallel expansion of storage, treatment and supply to the water-scarce villages,

Figure 4. In Assangthang, women and children were often seen fetching water from their nearest running water source.

viz. Tinjhir, Boomtar, Kamrang, Assangthang and Solophok.

In order to fulfil their daily household demands of water, children and women often fetch water from the nearby running water sources (Figure 4). The survey also reveals that only a few people in the villages are aware of water-conservation techniques, in a state where it rains throughout the year. Only 29% of respondents were aware of water conservation and rainwater harvesting techniques and are also practising them at the domestic scale. Their means are indigenous, such as rooftop rainwater harvesting (Figure 5), which is one of the appropriate options for storing water for direct use (both domestic needs and irrigation). Rooftop rainwater harvesting can supplement domestic requirements in both urban and rural areas during lean periods. Also, traditional knowledge and beliefs are upheld for conserving natural springs. It is believed that spring water comes out where the Goddess lives; such sites are known as *Devithan* (Figure 5). Being considered as holy sites, people barely pollute these springs and their neighbourhoods.

Figure 5. Rainwater harvesting in a house in Assangthang village, Namchi (top) and Devithan, Gangtok (bottom).

In the state capital and its neighbourhood, no water-scarce areas were located. The major water source is the Ratey Chu rivulet originating from Lake Tamze. Although commissioned in 1968, this source provides enough water to the city and its neighbourhood, with an average of 135 litres per capita per day both in summer and winter. Due to regular assessments of the five parallel pipelines from the source to the storage tanks, 20 zonal reservoirs with enormous capacity and fully functional water treatment plant, the city rarely encounters water shortages. The present water supply system is sufficient for the local population as well as the floating population (tourists).

In general, proper planning and management is recommended for water conservation in Sikkim. Being one of the major sources of water supply, the springs should be supplemented by rainwater harvesting techniques. In the villages where springs give poor discharge, cleaning of spring passages and increasing the dimension of collector wells and tanks is advisable for better yield. Also the perennial springs, which have not been tapped so far, may be developed for sustainable water supply in the respective areas.

The existing capacity of the storage or zonal tanks should be increased for supply of sufficient amounts of water to consumers. In many places, the water used for drinking is found to be polluted. Thus, proper information on preventive measures is to be dispersed to the local people before any such usage. Social awareness has to be created at all levels to educate and make people aware about the adverse impacts of wasting water, measures to access safe drinking water and the benefits of conserving water in the hills.

Hydel power projects

Being a renewable and efficient source of energy, hydel power promises a prosperous future for the coming generations. With nearly 30 projects, Sikkim has the maximum per capita hydel power projects in India. The rivers in the state, which contribute greatly towards power generation, are shown in Table 2.

The major focus of the work presented was on the NHPC Teesta Stage V project at Singtam. This stage produces a total of 510 MW power, of which 12.5% (67 MW) is given to Sikkim for free. Due to the numerous power projects, the state rarely experiences power shutdown. However, these projects demand numerous dams and

Table 2. Major hydel power projects in Sikkim[16]

River	Percentage of hydel projects	Installed capacity (MW)
Rongnichu	2	96
Rangpochu	3	151
Dikchu	3.5	195
Rathongchu	3.5	197
Lachen	4	210
Rangyong	6	280
Lachung	6	297
Rangit	7	342
Teesta	65	3340

concrete constructions on or near flowing rivers. This not only affects the ecosystem of living beings, but also forces them to adapt in nearly unlivable conditions.

The household surveys in the locality, i.e. in Singtam market, Sirwani, Dalep and lower Bermiok area, reveal the suffering of the people due to recurrent landslides, unsafe accommodations, ambiguities in compensation for relocation, human rights and security issues, employment insecurity and many other factors that need immediate attention of the general community. While surveying the local people around the power station, it was astonishing to find out that about 80% of them are against such power projects. On the contrary, 80% of the people in Gangtok and Namchi support such power ventures. This could be because they do not experience the immediate aftereffects of these projects, except the unremitting power supply.

The recent earthquake of magnitude 6.8 on the Richter scale, which hit the state on 18 September 2011, not only took many lives but also resulted avalanches and mudslides. It led to the destruction of water pipelines and almost no supply of drinking water in the region. The majority of the population in the affected area relies on water streams and falls, which have become muddy due to consequent landslides. It is another reminder of the dangers in the world's youngest, fragile and unstable mountains. Also, the quake has raised many questions regarding safety and security of hydel power projects in an earthquake-prone state like Sikkim. Dawa Lepcha, leader of the Affected Citizens of Teesta [ACT], mentioned (during an interaction) that this is why ACT opposes construction of too many hydel power plants in Sikkim.

Conclusion

There is insufficient information about water security and harvesting in Sikkim Himalaya. This study reveals that the region, despite being a water feeder to planar India, suffers water shortages and crisis in the South district, one of the most populated districts after East Sikkim. Many people in the vicinity are not aware of the available water quality and water conservation techniques. Majority of water samples not only contain coliform bacillus, but also have high basicity; only a few exceptions were found. In order to improve the quality and quantity of water in the region there is need for an integrated approach, planning of research into water resources and their management and educational outreach. This work may also help policymakers as well as the public to understand the implications of receding water resources in the mountains and to search for potential alternatives before any severe crises occur.

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ACKNOWLEDGEMENTS. I am indebted to the Winter Sojourn Team, Sikkim University and Government of Sikkim for their support and assistance during the field and laboratory work. I thank Dr U. K. Shukla, Department of Geology, Banaras Hindu University, Varanasi for his useful comments on the manuscript.

Received 20 October 2011; accepted 17 April 2012