Monitoring Himalayan glaciers

Snow and glaciers are vital to mankind as they play a critical role in making our rivers perennial and serve as a sensitive indicator of climate change. In the Himalayas as well as in other parts of the world, mountain glaciers are retreating in response to climatic warming[1].

As glacial dimensions change with climate, it is important to assemble the scientific information about future changes in the snow and glacier covers and their influence on stream run-off. Compared to all the mountainous regions of the world, the Himalayan glaciers constitute the large part of freshwater reserves outside the polar regions. The Himalayan glaciers are located in subtropical, high-altitude regions, predominantly of valley-type and many of them are covered with debris; these characteristics make them unique compared to other glaciers in the world. Considering the importance of these natural resources, the Ministry of Environment and Forests (MoEF), Government of India (GoI) has assigned a study on inventory and monitoring of these glaciers in the Indian Himalayan region to the Space Applications Centre (SAC), Indian Space Research Organisation, Ahmedabad, with joint funding by MoEF and the Department of Space (DoS), GoI.

Snow cover has been monitored regularly for the entire Himalayan region during 2004–2005 and 2007–2008. The inaccessible and hostile terrain of the Himalayas makes data collection difficult; hence space-based monitoring of these glaciers was found to be a viable option. This monitoring work by SAC took four years of efforts with the collaboration of 14 Indian research and academic organizations. In May 2011, MoEF presented the results of this work to the scientific community and the environmentalists[2]. According to this study, there are 32,392 glaciers in the Indus, Ganga and Brahmaputra basins draining into India. The country alone has 16,627 glaciers, covering an area of 40,563 sq. km. This work is of great significance as 2500 glaciers have been monitored to estimate glacial advance.

In 2003, on the recommendation of the peer-review committee of remote sensing and GIS application in the area of environment and forests, the National Natural Resource Management System (NNRMS) standing committee identified four major thrust areas: mapping of forest type on 1 : 12,500 scale; mapping of wildlife sanctuaries and national parks on 1 : 12,500 scale; coastal studies (including mangroves and coral reefs), and studies on snow and glaciers to be taken up during the 10th Five-year Plan. In view of the above, MoEF has constituted four task teams for each environmental theme. The snow and glaciers task team drafted a detail proposal to study the Himalayan glaciers which was accepted to be implemented as a joint venture with DoS.

Similar types of study have been done before, but they were at a small scale. Studies in the Baspa basin have shown an overall 19% deglaciation from 1962 to 2001 (ref. 3). Glacial retreat was estimated in the Baspa basin using stereo images of a remote sensing satellite. The retreat varied from 90 to 923 m between 1962 and 1998. Data on the Himalayan glaciers compiled from various sources suggests that they are retreating at varying rates, and maximum retreat of 34.62 m/yr has been observed at Meola glacier in Dhauliganga river basin.

The amount of glacial retreat depends upon overall mass balance and rate of melting at the terminus[4]. Debris cover can influence rate of melting at the terminus, as excessive debris retards melting and protects a glacier from retreat. Heavy debris cover makes small glaciers in the Himalayas less sensitive to climate change, in contrast to the Alps and Trans Himalayas, where small glaciers react more quickly to changes in mass balance and climate change[5].

Anil Kulkarni (SAC), who carried out studies in Bapsa as well as a few other basins and worked as a team member in MoEF and SAC joint project believes that wide valley, gentle slope and low altitude are the major causes for rapid retreat of the glaciers. According to him this massive retreat will continue in future and will have a profound effect on stream run-off of the rivers. 'Similar pattern of retreat is observed in many valley glaciers in the world. Therefore, to understand the proper pattern of glacial retreat, it needs to be monitored annually,' he said. Kulkarni further added, 'The Himalayas possess one of the largest resources of snow and ice, which act as a huge freshwater reservoir; monitoring the glaciers is important to assess the overall reservoir health'.

According to Ajai (Project Director, SAC), 'Himalayan glaciers in the Indian subcontinent are broadly divided into three river basins, namely Indus, Ganga and Brahmaputra. These glaciers are important source of freshwater for northern Indian rivers and water reservoirs. For water resources planning and management in North India, it is essential to study and monitor Himalayan glacier and snow cover.'

Monitoring of these resources is important for the assessment of water availability in the Himalayan rivers. Hence the project was framed with four strong objectives, namely snow-cover monitoring, glacier inventory, glacier retreat and glacier mass balance. Snow cover was monitored for 33 Himalayan basins for four consecutive years beginning from 2004, using an algorithm based on normalized difference snow index. Glacier inventory was carried out in the Indus, Ganga and Brahmaputra basins on 1 : 50,000 scale using satellite data of the period 2004–2007. Under this inventory mapping of features of glaciers was carried out on 37 parameters defined by UNESCO; at the same time 11 other parameters were added by SAC.

For the three basins, 1152 glacier inventory map sheets were prepared at 1 : 50,000 scale for the glaciated area of the Himalayas. The Indus, Ganga and Brahmaputra basins have been covered in 483, 203 and 544 map sheets respectively, with an overlap in 78 map sheets. The inventory maps and datasheets were prepared to cover all glaciers in these three basins located within India, or located outside but draining into India.

The glacier inventory datasheet with 37 parameters was prepared for each glacier. The three basins put together have 71,182.08 sq. km of glaciated area, with 32,392 glaciers. The Indus basin has 16,049 glaciers occupying 32,246.43 sq. km of glaciated area. The 18 glaciated sub-basins in the Indus basin have been mapped. The Ganga basin has 6237 glaciers occupying 18,392.90 sq. km of glaciated area. There are seven glaciated sub-basins in the Ganga basin. The

Brahmaputra basin has 10,106 glaciers occupying 20,542.75 sq. km of glaciated area. The 27 glaciated sub-basins in the Brahmaputra basin have been mapped.

It was observed that the percentage of accumulation area was highest in the Indus basin compared to the other two basins; however, it was almost similar for the Ganga and Brahmaputra basins. The ratio of accumulation to ablation area was also high in the Indus basin, and it was almost similar for the Ganga and Brahmaputra basins. This indicates that the glaciers of the Indus basin have larger feed area and hence are relatively more stable compared to the other two basins. The percentage of ablation area debris cover was almost similar for the Ganga and Brahmaputra basins, and low in the Indus basin. The ablation area ice exposed was highest in the Indus basin, and it was almost equal for the Ganga and Brahmaputra basins. Also, for these basins the accumulation–ablation area ratios were low and most of the glaciated areas had varying amounts of debris cover. The thick debris cover plays an important role by stopping the heat from sun rays in reducing the melting of glacier ice. However, the status of these glacier features depends on its altitude and latitudinal distribution.

The mean area under various glacier classes like accumulation area, ablation area, glacierets and snow fields, supra-glacier lakes and moraine-dammed lakes area have been studied for the three glaciated basins. The Indus basin has high mean accumulation, low mean ablation area along with low mean supra-glacial lake and mean moraine dammed lake area, which shows that this basin is more stable compared to the Ganga and Brahmaputra basins. It has been observed that low mean accumulation area of the Brahmaputra basin along with relatively higher mean area for supra-glacial lake and moraine-dammed lake could be serious for glacier health and stability, compared to the Ganga basin which has relatively high mean accumulation area and high mean ablation area.

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RESEARCH NEWS

Nanostructured carbon materials in water sterilization/purification

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The discovery of fullerenes in 1985 by Smalley and co-workers[1] has opened the gate for the entry of several synthetic nanostructured carbon allotropes like carbon nanotubes (CNTs)[2–4], carbon nanohorns, cup-stacked CNTs, carbon nanotori, carbon nano-onions, nanobuds[5], graphene[6], carbyne[7], etc. into the wondrous world of carbon nanomaterials. These carbon nanomaterials with unique mechanical, thermal and electrical properties hold great promise for many technological applications.

It has been estimated that around 1.2 billion of the world's estimated 6.5 billion people lack access to clean water[8,9]. The UN prediction of 40% increase in population[10] by 2050 will further worsen the clean-water supply situation. As many parts of the world witness serious pollution of groundwater and surface water[11,12], the demand for safe, affordable, robust and sustained methods for water purification is increasing throughout the world[13]. The advocates of nanoscience and nanotechnology believe that nanotechnology can offer much promise for meeting this demand.

Two approaches are envisaged to tackle the problem of removal of bacteria and other organisms from water. In one method the pathogens are removed by filtration (size exclusion of bacteria) using a device with CNTs[14]. The other approach exploits the bactericidal property of silver nanowires (AgNWs) and uses a three-component system (*vide infra*) which inactivates bacteria[15].

In 2004 Srivastava *et al.*[14] reported fabrication of free-standing, monolithic, uniform macroscopic, hollow cylinders having radially aligned CNT walls, with diameter and length up to several centimetres. These cylindrical membranes act as filters and have been shown to be effective in the filtration of bacterial contaminants such as *Escherichia coli* or the nanometre-sized poliovirus (~ 25 nm) from water. One advantage of this method is that these macro filters can be cleaned for repeated filtration through ultrasonication and autoclaving.

In the second strategy, Schoen *et al.*[15] took advantage of the unique ability of AgNWs and CNTs to form complex multiscale coatings on cotton to produce an electrically conducting and high surface area device for the active, high-throughput inactivation of bacteria in water. As Ag is an effective bactericidal agent, AgNWs are used in the device. AgNWs also form an efficient electrical transport network in filters. CNT coatings offer good electrical conductivity over the entire area of the device. Figure 1 gives a summary of fabrication of this device. Cotton was soaked in the CNT ink prepared by dispersing CNTs in water containing the surfactant sodium dodecylbenzenesulphonate (Figure 1 *b*). The cotton was then rinsed with distilled water to remove excess surfactant. A