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GUEST EDITORIAL

Predicting and Managing Extreme Rainfall

India seems to lurch from one major natural disaster to another. We have had major earthquakes, tsunami, floods and droughts during the last decade. Our ability to predict and minimize the impact of these disasters has not improved a lot. A spell of torrential rainfall in Uttarakhand from 15 to 17 June 2013, caused a huge loss of life and a need for a large scale evacuation of at least 100,000 people stranded in remote areas. Did we have the scientific expertise to predict these events? Was the expertise available and used wisely to reduce the impact of these events?

The computer models used by India Meteorological Department (IMD) predicted on 14 June that rainfall in Uttarakhand will exceed 100 mm/day in many mountainous areas during 16 and 17 June. This should have alerted those involved in the management of disasters. The consequence of such a heavy rainfall event on floods, landslides, however, seems to have not been appreciated. The Central Water Commission which is responsible for flood prediction also appears to have failed to do the job. They should have sent SMS to all administrators in the districts of Uttarakhand. There are many mathematical models available to predict floods and landslides once the rainfall amount is known. Bangladesh has created such a flood forecasting system that can predict floods up to one week in advance (*Nature*, 3 January 2013, **493**, 17–19). In India, the National Disaster Management Agency (NDMA) that was established more than 7 years ago should have taken up this task. The NDMA was supposed to promote a culture of prevention and preparedness. But, there is no evidence of that so far. Prof. Dave Petley (Durham University, United Kingdom) has said ‘The lack of coherent information from government continues to amaze me, especially when compared with the clarity of data that is produced in similar situations in other poor countries, most notably the Philippines’ (http://blogs.agu.org/landslideblog/).

The cause of the debris avalanche in Kedarnath valley that killed hundreds of pilgrims is still a puzzle. According to the data from the satellites, the rainfall in this valley was high on 16 and 17 June, but not unusual. Many people have speculated that a cloud burst could have occurred. A cloud burst is an intense rainfall event with rainfall intensity above 100 mm/h. There was no automatic rain gauge in this valley. But satellite data indicates that the highest rainfall was around 20 mm/h for few hours. During the months of July and August this region would have experienced higher rainfall. The catastrophe that struck Kedarnath valley could be on account of a glacial lake outburst flood (GLOF). GLOF occurs when a lake is created behind a glacial moraine and this dam built by moraine breaks and all the water in the lake gushes out. There is, however, no evidence to indicate that a large lake existed behind a glacial moraine in this valley before the disaster. A landslide on 15 June may have blocked River Mandakini and the water that was dammed behind the landslide may have gushed out in the early morning of 17 June.

The region around Kedarnath temple is vulnerable to landslide and hence fifty years ago pilgrims did not stay overnight near the temple. The Geological Survey of India had warned the Uttarakhand government almost ten years ago about the threat of landslides in this valley. But the warning seems to have been ignored.

There have been many intense rainfall episodes in Uttarakhand during the past ten years and most of them occurred in the months of July and August. These caused landslides and deaths; but, did not receive as much media attention because they did not occur near any famous pilgrim centre. This is the first time such an intense rainfall has occurred in the month of June and covered the whole of Uttarakhand and just not one valley.

Can these extreme rainfall events in Uttarakhand be attributed to global warming? There has been a 50% increase in extreme rainfall events during the past 50 years in India (*Science*, **314**, 1 December 2006, 1442–1445). Most climate models show that, extreme rainfall events increase in response to increase in greenhouse gases. The greenhouse gases are not the sole agents responsible for extreme rainfall events. However, they amplify the extreme rainfall induced by other causes. In Uttarakhand, the extreme rainfall event on 16 June was triggered by an interaction between a mid-latitude weather system and the monsoon. We know, however, that extreme rainfall events will increase as global warming proceeds unabated. Hence, it is absolutely essential for us to be prepared to tackle more extreme rainfall events in this region in the future.

The major impact of the high rainfall in Uttarakhand in June has been large number of landslides that blocked the roads, and hence, hampered the rescue efforts. There has been no systematic effort in India to predict the occurrence of landslides following a heavy rainfall event. The University of British Columbia in Vancouver, Canada has a 'Geophysical Disaster Computational Fluid Dynamics Centre' whose role is to predict disasters in mountainous regions in western Canada. In Uttarakhand, landslides occur on account of deforestation, heavy rainfall and earthquakes. The interaction between these three factors has not been fully explored. The Department of Earth Sciences in Indian Institute of Technology, Roorke has done a lot of research on landslides in Uttarakhand. But the government appears to have ignored the advice given by academic institutions. In India there is insufficient interaction between operational agencies and academic/research institutions in tackling problems of immediate relevance to the country. We can learn a lot about prediction of landslides in real-time from the methods adopted in Hong Kong, China, Indonesia and the Philippines. In addition to floods and landslides, the major impact of heavy rainfall in Uttarakhand was the destruction of buildings built along the banks of Alakananda and Bhagirathi rivers. This could have been avoided if there was strict enforcement of law regarding the building of structures on the banks of the rivers. In areas such as Uttarakhand there is very little flat land available for construction of buildings and hence there is a temptation to build structures in high risk areas. This must be curtailed. Civil engineers must look for innovative solutions for buildings in this region. The number of tourists and pilgrims visiting Uttarakhand has exceeded 25 million during the past few years. One must examine whether such a large influx of tourists in summer is sustainable in this ecologically fragile region. In most countries, there is usually an upper limit on the number of tourists allowed in an ecologically fragile region. In India no attempt has been made to restrict the flow of tourists and pilgrims to mountainous regions. More than 30 years ago the Nanda Devi Biosphere Reserve was created to preserve this unique Himalayan ecosystem. This concept must be enlarged to encompass other areas in Himalaya and especially in the state of Uttarakhand. This may not be easy, as we must find a way for people living in the State to prosper, without adverse impact on the environment. In this regard we can learn from the policies adopted by our neighbouring State of Bhutan to ensure that development does not have an adverse impact on the environment.

The building of large number of hydroelectric power plants in Uttarakhand has disrupted the smooth flow of rivers. The major portion of power generated by these plants is exported to other states, while the adverse impact of these plants is borne by the residents of Uttarakhand. The local requirement of power can easily be met by mini-hydro, geothermal and solar power plants that have less impact on the environment. The central government is, however, keen to build more hydroelectric power plants in the Himalaya, because, they have low greenhouse gas emissions and the capital cost is lower than solar power plants. This view is short-sighted, because, it does not account for the adverse impact of large hydroelectric plants in mountainous regions. We must learn from the large number of landslides induced by the huge Three Gorges dam in China. Some people have claimed that Tehri dam may have prevented catastrophic floods in Rishikesh and Haridwar. This may be true, but it ignores the adverse environmental impact of the dam around Uttarakashi.

In addition to improving our ability to predict natural disasters, we need to improve the way we communicate with the public during the disaster. On 17 June, many people were stranded between Devaprayag and Rudraprayag on the Rishikesh–Badrinath national highway because of landslides. There was no attempt to assist the stranded people to find alternate routes, out of the Alakananda valley. There was no authentic information on the state of the national highway. People had to fend for themselves and find a way out of the Alakananda valley. In an era of mobile communication, this should not have happened.

The manner in which the Indian army, air force, navy and volunteers from the mountaineering institute in Uttarakashi rescued more than 100,000 civilians trapped in high mountain regions is truly remarkable. A major natural disaster is very often a trigger for change. The Ministry of Earth Sciences established a state-of-the-art Tsunami Warning Centre after the disastrous tsunami in December 2004. Let us hope that the natural disaster in Uttarakhand will bring about a radical change in the way in which we predict, manage and adapt to heavy rainfall events in the future. This will be essential because global warming and earthquakes will pose many new challenges to the beautiful state of Uttarakhand in the near future.

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