Geophysical Research Abstracts, Vol. 9, 04048, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-04048

Hazard potential of seepages causing moraine dam break in the Bhutan Himalayas

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Due to global change the regional melting of glaciers in the Himalayas rapidly increased since the 1950ies as proved by remote sensing imageries from Nepal and Bhutan. The retreating glaciers form moraine dammed proglacial lakes, which have burst for several reasons and caused glacier lake outburst floods (GLOFs).

This paper deals with the hazard assessment of moraine seepages, which were described as one major factor causing a GLOF when the frontal and lateral moraines are destabilised by groundwater underflow resulting in dam failure. In total some 17 seepages in the vicinity of about 6 moraine-dammed lakes were investigated in Pho catchments of Northern Bhutan from 2000 - 2002.

Using a hand held WTW-thermometer the daily range and using TibDit temperature loggers with an accuracy of ± 0.3˚C and a resolution of ± 0.4˚C, the monthly and yearly range of water temperature of selected moraine seepages was monitored. In addition, information on the altitude of infiltration and on water age was assessed by interpretation of stable and instable isotopes.

In total we found four different classes of moraine seepages depending on the monthly and yearly range of water temperature regardless of their discharge, which varied from some centilitre/s up to some 1000 l/s. Seepages appear at both sides of the up to 100 m high moraines, mostly at the outer side towards the Pho River, and very seldom at the inner side facing the moraine dammed lake.

1. Type 1 seepage clearly represents river water from the nearby passing Pho River, which infiltrates the moraine some kilometres upstream and discharges through pipes of the lateral moraine damming the nearby Thorthormi Proglacial Lake. The daily range of water temperature of these seepages of in total 10 l/s parallels the water temperature of the Pho River.

2. Type 2 seepage of 1-2 l/s discharges a tributary of the Pho River when passing the very coarse blocks of up to one metre in diameter towards the Proglacial Lake (Luggye Tsho).

3. Type 3 seepage was identified as seasonal overflow of Thorthormi Proglacial Lake close to the lake outlet, probably situated above a former horizon up to which the very coarse moraine was clogged by fine-grained material. The daily range of water temperature of seepages discharging 20-30 l/s differs slightly from the temperature of the lake water at Thorthormi outlet.

4. Type 4 seepage is characterised by nearly constant cold temperature of about 1.2˚C throughout the year (!) discharging from a moraine situated between two retreating glaciers. The cold temperature is neither a direct flow from the nearby Raphstreng Lake nor a groundwater flow passing dead ice, because no glacier ice was detected along the potential groundwater flow path by multielectrode resistivity measurements. The infiltration area of seepage 4 water can be identified as a local hilly region between the side moraines of the Bechung Glacier and the Raphstreng Lake. We suppose that the moraine-dammed Bechung Glacier cools the precipitation water when passing the outer side of its moraine dam. Because a daily influence of aerial temperature on water temperature is missing, the groundwater flow can be estimated at depths below 30 metres.

In total we conclude, that water from the proglacial lakes does not seep through the moraine dams and therefore these seepages described hardly weaken the dams by suffusion of the extremely bad-sorted moraine material of the frontal and lateral moraines. For GLOF-scenarios in the Bhutanese Himalayas therefore were calculated for overtopping flood waves caused by mass movements, dam break caused by melting dead ice, dam failure caused by earthquakes, and flood waves caused by piping effects from glaciers or outburst events from glacier lakes situated upstream.