Sediment transport in Indian Himalayan rivers: Issues and challenges

The Himalayan region is recognized as "*Water Tower of Asia*" and plays a critical role in the hydrological cycle of major Asian rivers including e.g., the Ganges, the Yamuna and the Brahmaputra and their tributaries in India (Fig. 1). The sediment supply and transport in these rivers is normally much higher than the sediment transport in other rivers and is considered to be highest in the world. Wasson (2003) suggested that about 80% of the sediment is believed to originate from the high Himalaya and about 20% from the lesser Himalaya, due to steep and rugged terrain in terms of topography, fragile geology, snow and snowmelt, uneven intense rainfall and supraglacial debris. In this context, few records of sediment transport studies are found in Himalayan river basins in comparison to hydropower development and hydrological studies. About 90% sediment transport occurs during the monsoon season. High sediment loads in Himalayan rivers results in major problems such as river bank erosion, blockages to river channels, damage to turbines, reduction in the quality of water supplies, disturbance of riverine ecosystem services and transport of chemical pollutants. Furthermore, erosion and sedimentation may be a threat to the variety of organisms and habitats. Therefore, understanding the spatial and temporal patterns of the sediment transport and sediment yield in these river basins is quite important for effective water resource development in the Himalaya.

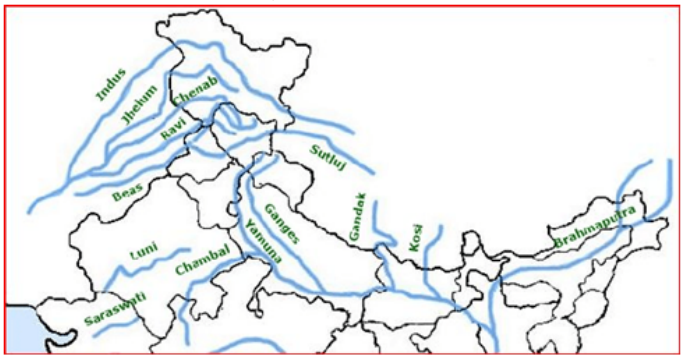

Fig. 1. River system of Himalaya

Factors affecting sediment transport:

Sediment load in most of the Himalayan rivers varies spatially and temporally and it is influenced by key factors such as mean trunk channel gradient, relief ratio, runoff, basin lithology, and recurring earthquakes. Glazyrin *et al.,* 1995 have stressed the importance of additional factors in sediment generation in mountainous regions to include tectonics and seismic activity, glacial area, proportion of snow and basin area. Furthermore, few researchers argued that a number of environmental variables such as topography, hydro-climatology, lithology, land use and soil erodibility are also affect sediment yield. Anthropogenic interventions such as unscientific method of road construction, land use changes, mining activities, soil and water conservation measures, sediment control programmes also affect the process of sedimentation.

Published literature highlights that various researches have been conducted on mountainous rivers around the globe to identify the effect of these factors, but very little research are available for Indian Himalayan rivers which is due to the lack of sampling stations, reliable and consistent sediment rating equations and inaccessibility of the area.

The Ganga–Brahmaputra River carry huge sediment loads because they flow over the easily erodible carbonates and through the Himalayan terrains (Chakrapani 2005). Sediment transport load is comparatively higher in the Brahmaputra (721Mt/year) than the Ganges river (316 Mt/year), because the aggradation rate of the channel bed is much greater for the Ganges (Lu *et al.,* 2009). Various researchers highlighted that vegetation has the major control on sediment production. The effect of changes in land use pattern, afforestation/deforestation activities, was studied by many researchers. Wasson *et al.,* 2008 confirmed that deforestation had impacts on soil erosion and river sediment load for a large erosional event in the catchment of the Upper Ganges, with landslides occurring in deforested areas. For sedimentation problems in the Himalaya, human activity has less impact on the sediment load than natural factors. In Himalyan region, it is estimated that the annual average loss rate of reservoir storage capacity due to reservoir sedimentation is 0.78%. As a result, storage capacity of reservoirs in this region is lost rapidly due to sedimentation deposition. To cope with sedimentation problems and develop sustainable reservoir operation and management strategies, engineers and researchers have developed many innovative methods, such as drawdown flushing and empty flushing, venting turbidity currents, dredging, etc.

Future Action:

(i) Future work of erosion and sedimentation management should be based on a more scientific and sound ground;

(ii) More coordinated and integrated approach should be taken to manage land-water interaction and for tailor-made policy at catchment level;

(iii) At present policies at three levels (international, national, and regional) is in need. Establishing law enforcement teams is one of the measures to be adopted;

(iv) The concept of "harmony between mankind and nature" has become more popular in dealing with their relationship. Thus, management should be the basic concept of river planning and design; and

(v) International co-operation includes many aspects of works on erosion and sedimentation, particularly in the management aspect. The challenge of modern river management is how to allocate water between competing uses while still maintaining ecosystem services.

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