Chemical weathering in the river basins of the Himalaya, India

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Rivers transport weathered materials from land to the ocean. The chemistry of river waters is dictated by supply of various elements from both natural and anthropogenic sources. Among the natural sources, chemical weathering of the drainage basin is the dominant component, a process which consumes atmospheric CO_2. On timescales of millions of years, atmospheric CO_2 balance and hence global climate is influenced by chemical weathering process, silicate weathering in particular. The suggestion that silicate weathering in the Himalaya may be a driver of global cooling during the Cenezoic[1–3] has prompted many studies on rivers draining the Himalaya, especially the source waters of the Ganga–Brahmaputra. This article reviews some of these studies and presents the current thinking on this topic.

Keywords: Chemical weathering, Himalaya, CO_2 draw-down, Ganga–Brahmaputra, Deccan.

CONTINENTAL weathering and erosion are major components of the exogenic cycles of elements on the earth. Weathering breaks down rocks and the resulting dissolved and particulate materials are transported by rivers to the sea. Chemical weathering of rocks and minerals determines the flux of dissolved materials carried by rivers whereas physical weathering regulates the particulate transport. This makes the study of dissolved and particulate components of rivers important to characterize and quantify weathering and erosion. The study of chemical composition of river water is important not only for determining erosion rates, but also to learn about sources of elements to rivers, mineral weathering and elemental mobility and uptake of CO_2 during chemical weathering. In addition, information on river chemistry is essential to assess water quality for domestic, agricultural and industrial usage.

During the past 2–3 decades, many studies have been reported on the chemical and isotopic composition of Indian rivers[4–10]. Among the river basins studied, those from the Himalaya have received more attention mainly to elucidate the coupling between tectonics, weathering and climate. In recent years, there have also been studies of rivers draining the Deccan traps[11,12] to determine the role of their weathering in contributing to global riverine fluxes and atmosphere CO_2 draw-down. In this article, some of these issues, particularly those pertaining to silicate weathering rates of Indian river basins, associated CO_2 consumption and factors influencing them are reviewed based on available data on major ion chemistry of selected rivers.

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Data source

India has a number of rivers all of which are fed mainly by water from monsoon rains. In addition, the rivers draining the Himalaya receive water from glaciers/snow melt during summer. Table 1 summarizes physical characteristics of a few selected rivers from India[13,14]. The rivers in India drain a total area of $\sim 3.1 \times 10^6$ km^2 and annually discharge ~ 1650 km^3 of water. This translates into a mean run off of about 500 mm yr^{-1} for the entire India. The water discharge from India accounts for ~ 4.5% global river discharge. The pattern of monthly discharge of rivers mimics that of rainfall, with maximum for most rivers during July–August, coinciding with the peak of the more intense south-west monsoon rainfall (Figure 1). Some of the rivers draining the eastern and peninsular part of India also receive water from NE monsoon rains, their discharge therefore show effect of these rains as well (Figure 1).

Water chemistry

Sources of major ions to rivers

The chemistry of river water is dictated by a number of sources. These include:

Rain/precipitation. The primary source of water for rivers is rainfall and snow melt; which makes their composition an important component of river water chemistry. It is their chemistry which forms the base line for the evolution of river water composition. Rain water composition is location-dependent, near the coasts it is dominated by sea salt and in these regions the elemental ratios in rains are more similar to those in ocean. In inland regions, sea salt, continental dust, biogenic and anthropogenic inputs contribute to chemistry of rains. The relative significance of marine contribution to rain decreases with distance away from the coast and generally levels off to a constant low value inland. Na^+ and Cl^- are the dominant components of coastal rains, this changes to Ca^{+2}, HCO_3^- and SO_4^{-2} inland. Typical major ion