HYDROCHEMICAL CHARACTERISTICS OF HEADWATER STREAMS IN THE MIDDLE HILLS AND HIGH MOUNTAINS OF THE NEPAL HIMALAYAS

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The impact of anthropogenic pollution from industrial and agricultural sources on water chemistry has concerned environmentalists and scientists for the past two decades. Consequently, the chemistry of headwater streams, lakes, and lowland rivers has been monitored widely in Europe and North America, in an effort to define and quantify these anthropogenic impacts. An understanding of how anthropogenic pollutants affect water chemistry and hence the ability to predict the location and severity of potential impacts, can be achieved only through knowledge of hydrochemical processes in pristine waters with similar physico-chemical characteristics. If a sufficiently detailed knowledge of pristine or baseline water chemistry is available, the effects of local pollution stemming from land use and land management, and of regional pollution from atmospheric deposition of acidic oxides, for example, can be quantified. This study presents the first wide-scale surveys of the chemistry of medium to high-altitude first-order streams in the Nepal Himalaya.

The data is reported from seven regions of the Nepal Himalaya, situated around significant river basins (fig. 1), namely the Everest region (Dudh Kosi), Annapurna region (Modi *Khola*), Langtang region (Langtang *Khola*), Makalu region (Arun and Barun *Khola*), Simikot region (Mugu and Humla Karnali), Dunai region (Churto *Khola*), and Nuwakot region (Likhu *Khola*). Sampling was carried out during February and March 1992 in the Everest, Annapurna, Langtang, and Nuwakot regions and during November and December 1994 in the Dunai, Simikot, and Makalu regions. A repeat survey of the Langtang region was carried out in 1994 and the hydrochemical data is consistent between the two surveys of the region. At both times, flows were low at all elevations. Sampling at low flows, during a prolonged dry season, was chosen primarily to reduce the variance in stream chemistry due to high flow events; this would produce regionally comparable data sets. However, an important consideration during this period was ease of access.

Detailed geology of these areas is poorly documented and the dominant bedrock geology is reported to consist of pre-Cambrian gneiss (Figure 1). Large areas of low-grade metamorphic green schist were noted in the field in all the sampling regions. The Central Himalayan Thrust fault is associated with a calcareous formation and outcrops in many of the regions. Natural vegetation in all the regions is strongly zoned by altitude and so reflects a north (high mountains characterised, above the tree line but below the zone of permanent snow cover, by juniper, rhododendron shrubs, and grassland) to south (middle hills dominated by terraced cultivation and grazing land) gradient.

Results show that stream chemistry in mid-high altitude Himalayan mountain streams is well buffered, with pH generally in the 7.0-8.5 range. A number of sites within each region may, however, be sensitive to acidification with pH in the 5.5-6.5 range. Bicarbonate is the dominant anion and Ca and Mg the dominant cations, but there exist significant hydrochemical differences among the seven regions (Figure 2). Bedrock geology is the main influence on water chemistry, both among and within regions. Ion concentrations tend to decrease with altitude, reflecting differences in land use, land management, natural vegetation, and atmospheric deposition, all of which are correlated to altitude. Terraced agriculture also contributes significantly to differences in chemistry, both between and within regions. Water-draining agricultural catchments have higher concentrations of acid anions (Cl, SO_4), probably as a result of mineral fertiliser inputs and trace metals (Fe, Al, Ba, Sr, Mn, Si, and F), due to increased weathering. Locally high concentrations of trace metals were common in all high mountain regions.

In general, the high-altitude forest and alpine scrub-covered catchments in the Himalaya are unlikely to be sensitive to the atmospheric deposition of acidic pollutants. Many of these streams are fed by glacial meltwater. The waters from these catchments generally have high background concentrations of SO_4 derived from weathering sources. High pH indicates that a large buffering capacity exists within the system and that further additions of anthropogenic SO_x will be readily buffered. However, these systems already show significantly high concentrations of NO_3. This is probably a result of the low biological requirements, given the poor vegetation and cold temperatures at high altitudes. Clearly a future increase in atmospheric NO_x deposition could exacerbate the situation and promote yet higher concentrations. While this is unlikely to cause acidification of these upland streams, and the biological implications of increased NO_3 concentrations are not known, downstream eutrophication problems may occur.

The close links reported between the stream invertebrate community structure and stream chemistry in these environments and land-use changes could have biological consequences through changes in water chemistry. Future surveys of water chemistry and biology are required in similar Himalayan environments to provide the necessary baseline data so as to assess the damage caused by anthropogenic influences; in particular, the impact of land use and land cover on stream chemistry should be quantified so that the sensitivity of these systems to anthropogenic pollution can be assessed. This is particularly important, given the desire to maintain ecosystem stability and biodiversity in the face of the continued development of these areas, in response to increasing population pressure in the middle hills and increasing tourist pressure in the high mountains.•

Figure 1. Location of the seven regions - sampled and simplfied regional geology

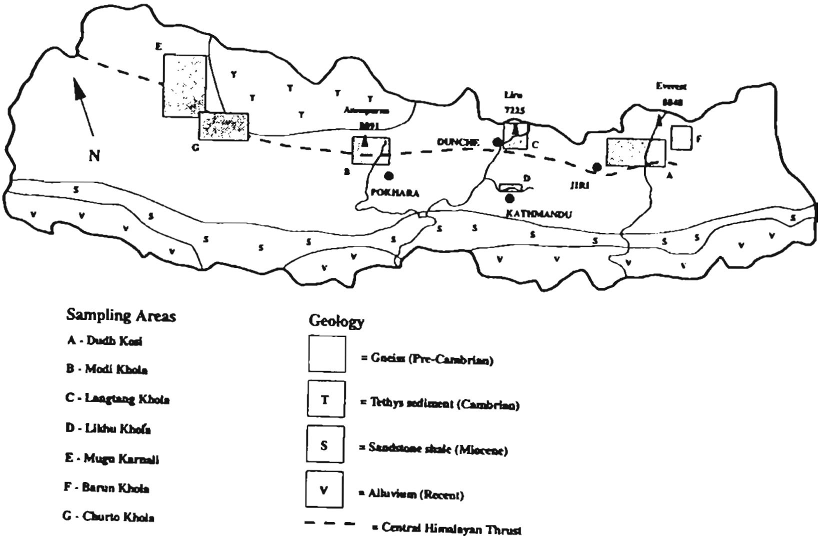

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Figure 2. Hydrochemical characteristics of each region - mean concentration, range of the mid 50% of values, interquartile range, and outliers/extremes