STREAMWATER ACIDIFICATION IN RESPONSE TO ANTHROPOGENIC POLLUTION INPUTS AT FORESTED AND CULTIVATED CATCHMENTS IN THE MIDDLE HILLS, NEPAL

ROBERT COLLINS, ALAN JENKINS AND DAVID BOORMAN
Institute of Hydrology, Wallingford, Oxon, UK
PAUL WHITEHEAD
Department of Geography, University of Reading, UK

The sustainable use of land, water, and agricultural resources is an essential component in the future development of Asian third-world countries, and especially those regions bordering the Himalayas where the rapid population growth is predicted to continue. This population pressure results in an intensification of agriculture through multiple annual crop rotations, supported by large applications of inorganic and organic fertilisers and the expansion of cultivated land to steeper hill slopes and previously forested areas. Continued and excessive application of mineral and organic fertilisers in order to increase crop yields may, however, result in detrimental effects in the form of soil and water acidification as well as potential downstream eutrophication. The problem may be exacerbated by the deposition of acidic oxides from fossil fuel burning; and it is predicted that the rapid industrialisation of many Asian countries will increase air polluting emissions in the future.

The Land Use, Soil Conservation and Water Resource Management Project was established in 1991 by the Institute of Hydrology, UK; the Royal Geographical Society, and the Department of Soil Science, His Majesty's Government of Nepal. The study focussed on the Likhu *Khola* watershed in the middle hills of Nepal. One aim was to quantify the impact of anthropogenic pollution on stream chemistry. The watershed is located approximately 10km north of Kathmandu and industrial emissions emanating from Kathmandu Valley cause acidic deposition. In addition, terraced agricultural land throughout the watershed is treated with substantial applications of both mineral and organic fertilisers. Urea and ammonium sulphate are the main forms of mineral N fertiliser used, with c.140 - 200kg ha^{-1} applied to each rice crop with normally two crops per year. Additionally, six to eight tonnes per year of farmyard manure are applied to the rainfed terraces.

Stream chemistry samples were taken at high frequency over a period of five days during storms in the monsoon season of 1992. The stream chemistry response to rainfall in a north-facing subcatchment comprised of c. 50% terraced agriculture and 50% second generation, mixed deciduous hardwood forest in its headwaters (fig. 1). The storms monitored were relatively moderate in magnitude and intensity, resulting in peak flows of only c.1m^3 s^{-1}. The stream chemistry response to rainfall was characterised by rapid decrease in base cation concentrations. Base cations are predominantly derived from the weathering of gneissic bedrock so that a relatively constant source becomes diluted by the increased flow. This decrease in cations is accompanied by a concomitant increase in anions, predominantly fertiliser-derived SO4 and NO3, triggering a reduction in stream pH and significant decreases in bicarbonate alkalinity with each new storm event, although the streams quickly recover to mean concentrations. Continuous monitoring of pH was also carried out at the study catchments over four years, and, at this site, shows that acidic episodes with pH falling below 6.0 are common. In general, the geology of the watersheds imparts a strong buffer capacity to the streams to ensure that acidification is only transient although the data indicate a susceptibility to anthropogenic pollution in the form of inorganic fertilisers, the input of which is likely to increase in the future in line with the increasing population and demand for food.

In contrast to the agricultural catchments, a relatively pristine forested catchment demonstrates constant pH throughout the year. However, a storm event in July 1992 (Figure 2) demonstrates a clear sensitivity to acidification as the pH drops to a level consistent with the episodic acidification response observed in the cultivated catchments. During this single event the pH dropped rapidly from 7.0 to 5.5, indicating a potential for biologically-damaging acidic episodes in pristine forested catchments. Since fertiliser usage is minimal within this catchment, this event must have been driven by high concentrations of acidic anions in the rain, indicating an underlying vulnerability of both forested and cultivated catchments to predicted increased levels of acidic deposition in the future. Acidic episodes of this type are known to be biologically damaging to aquatic biota and have been identified as precursors to longer-term chronic acidification.

In conclusion, both forested and cutlivated catchments in the middle hills are susceptible to episodic acidification. The acidic inputs driving this acidification are atmospheric deposition and application of inorganic fertilisers. In the case of acidification caused by fertilisers, it is clear that the method of application could be changed to ameliorate the most severe effects. At forested sites, a reduction or slowing in the rate of emission of acidic oxides would stabilise the situation. Remedial measures to reverse soil and surface water acidification in NW Europe and N America were implemented too late to prevent losses of biological and economic resources, largely because the precursors to chronic acidification went unnoticed. In the Himalayas, an early indication of a potential problem has been observed and this provides the opportunity for remedial measures to be adopted without long-term loss of, or damage to, natural resources.

Figure 1. Stream chemistry response to rainfall in a north-facing subcatchment comprised of c. 50% terraced agriculture and 50% second generation mixed deciduous hardwood forest

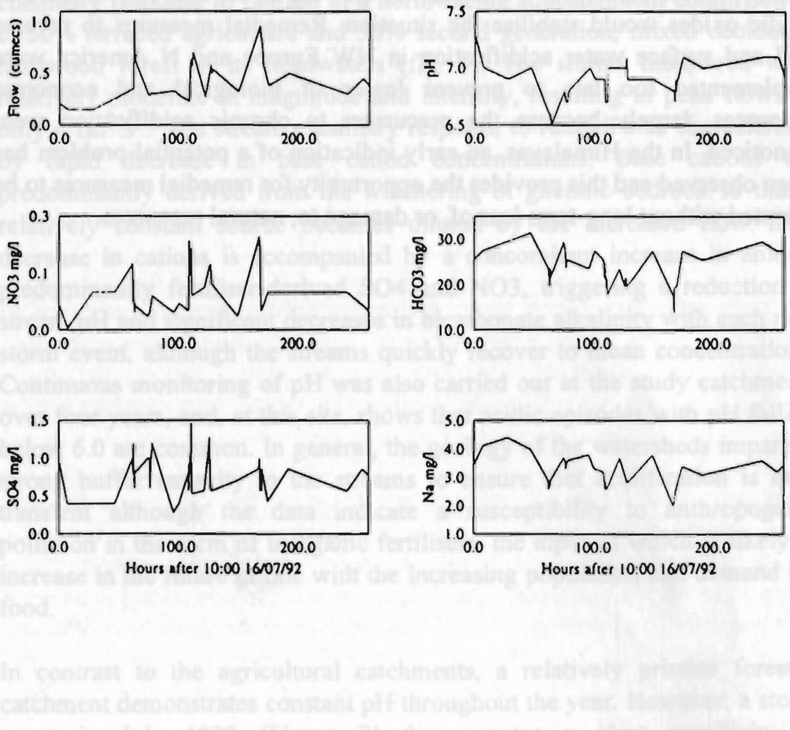

Figure 2. The stream stage, pH, electrical conductivity, and water temperature response to a rainfall event in July 1992 at a 100% forested catchment