Dissolved Mo and U in rivers and estuaries of India: Implication to geochemistry of redox sensitive elements and their marine budgets

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A R T I C L E  I N F O

Article history:
Received 20 April 2010
Received in revised form 9 September 2010
Accepted 12 September 2010
Editor: J.D. Blum

Keywords:
GEOTRACES
Uranium
Molybdenum
Estuary
Gulf of Cambay
Anthropogenic source
Sink of Mo

A B S T R A C T

Dissolved molybdenum (Mo) and uranium (U) concentrations were measured in five Indian estuaries; the Narmada, Tapi, Mandovi and the Mahi fall into the Arabian Sea and the Hooghly falling into the Bay of Bengal. Riverine Mo and U vary significantly, in the range of 1 to 80 and 0.02 to 19 nmol/kg respectively. The lowest Mo and U were observed in the Mandovi river, consistent with lateritic lithology exposed in its drainage, higher runoff and lower water-rock interaction. The Sabarmati has the highest U, 19 nmol/kg and sources from the groundwater having very high U concentration. The highest Mo (90 nmol/kg) is observed in the Mahi river and probably results from anthropogenic sources. Hooghly river seems to have high concentrations of Mo (14 nmol/kg) and U (8 nmol/kg) and are possibly derived from weathering of black shales of the Himalaya. Behaviour of Mo and U in all the estuaries analysed in this study is highly variable. Both Mo and U in the Narmada estuary during pre-monsoon and monsoon seasons and U in the Tapi estuary behave conservatively. Mo in the Tapi shows an addition in the mid salinity ranges (~4 to 12‰) and is sourced from anthropogenic activity probably related to effluent from industries situated along the estuary in this salinity range. Both dissolved Mo and U show their removal at lower salinity ranges in the Hooghly and the Mandovi estuaries. These estuaries are not sink of Mo in which significant amount of oceanic Mo along with riverine Mo is being lost. About 1.6 × 10⁶ and 2 × 10⁵ mol of Mo are being removed annually in the Hooghly and the Mandovi estuaries. Uranium removal is order of magnitude lower compared to Mo in both the Hooghly and the Mandovi estuaries. The loss of Mo and U in the estuaries are associated with mangrove swamps present in the estuaries which seems to be an important sink of the oceanic Mo and could represent its significant sink in oceanic budget of Mo.

The Gulf of Cambay has high dissolved Mo concentration compared to that of global average seawater value which is attributed to its supply from anthropogenic sources. Industrial effluent waste waters along with polluted rivers supply ~5 × 10⁵ mol of Mo annually to the Gulf of Cambay which could be derived from petrochemicals and pharmaceutical industries situated along the Gulf coast.

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1. Introduction

Estuaries represent transition zone between river and ocean where geochemical, biological and sedimentological processes are highly variable both spatially and temporally (Colodner et al., 1993; Dalai et al., 2005; Dellwig et al., 2007; Scheiderich et al., 2010). These processes determine the riverine contribution of various elements to the oceans. The study of the behaviour of various elements in the estuary therefore becomes important not only to understand their geochemistry but also to evaluate their marine budgets. Among the various groups of elements that are being investigated, one is the redox sensitive group that include U, Mo and Re. This group of elements finds applications in studies of marine paleoenvironmental conditions because of their property to be sequestered with the organic rich marine sediments (Ravizza et al., 1991; Colodner et al., 1992; Morford and Emerson, 1999; Dalai et al., 2002; Jaffe et al., 2002).

The dominant source of all these elements to the ocean is river input (Martin and Meybeck, 1979). In rivers these elements are derived from chemical weathering of various lithologies, an important one being organic rich sediments, black shales (Colodner et al., 1993; Jaffe et al., 2002; Singh et al., 2003). Recent studies, however, have shown that in some rivers anthropogenic sources can also be significant (Colodner et al., 1993, 1995; Peucker-Ehrenbrink et al., 2006; Rahaman and Singh, 2010). Available studies showed that the behaviour of these elements is complex (Emerson and Hausted, 1991; Colodner et al., 1993, 1995) and seem to depend on the regional environmental chemistry. For example both uranium and rhenium exhibit conservative and non-conservative behaviour in estuaries (McKee, 2008 and references there in; Colodner et al., 1993; Rahaman and Singh, 2010). Studies of Mo in estuaries are sparse (Colodner et al., 1993; Helz et al., 1996; Dalai et al., 2005; Audry...