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Multi-proxy evidence for compositional change of organic matter in the largest tropical (peninsular) river basin of India

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SUMMARY

The distribution and compositional changes of organic matter (OM) within the Godavari river system is increasingly influenced by reduced monsoon rainfall and an increased number of damming. To track these changes stable isotopes of organic carbon and concentrations of lignin phenols were analyzed in total suspended matter (TSM), sediments, agriculture soils and plants from Godavari basin. The results indicated that the upper tributaries drained heavier carbon ($\delta^{13}C_{org} = -20.4 \pm 2.2‰$) than the lower tributaries ($\delta^{13}C_{org} = -25.4 \pm 1.5‰$) owing to the regional vegetation in the upper to lower basins. OM originating from algae near dam impoundments was incorporated into TSM and sediment due to extreme drought condition. The organic carbon (OC) content was higher in TSM and in the sediment of the region after the middle reach dam (Sriram Sagar) than before (2.2 ± 1.6 vs. 1.0 ± 0.1% OC and 2.1 ± 2.3 vs. 0.6 ± 0.2% OC, respectively). The lignin yield ($\Lambda 8$) was lower in TSM and in the sediment after the dam impoundment than before (0.37 vs. 1.94 mg/100 mg OC and 2.9 ± 1.1 vs. 5.4 ± 2.3 mg/100 mg OC, respectively) due to an increased contribution of lignin free OC from algae and degraded soil. Less rainfall and dam impoundments enhanced the fraction of labile OM from freshwater algae and an estuarine phytoplankton bloom in the study year. Our study is the first to document lignin fluxes from an Indian monsoonal river (Godavari). The flux of lignin phenols of 7.26×10^9 g yr^{-1} is much lower than those of most world rivers except the rivers from polar arctic.

1. Introduction

OM in rivers is an integrator of terrestrial processes related to the lithology of river basins (Longworth et al., 2007) and its landscape (Bianchi et al., 2007a; Eckard et al., 2007). Terrestrial OM is a mixture of allochthonous (vascular plants and soil) and autochthonous (riverine/estuarine phytoplankton) materials. OM in plants and soil undergo primary degradation processes driven by bacterial and/or fungal action, which alters their molecular composition before their input into riverine environment (Hedges et al., 1986). Riverine OM incorporated into coastal marine sediments is an important component of the marine biogeochemical cycle (Keil et al., 1994). The nature of riverine OM is broadly responsive to processes of the terrestrial carbon cycle such as continental and chemical weathering (Galy and France-Lanord, 1999; Sempéré et al., 2000; Barth et al., 2003). In addition, anthropogenic processes such as agricultural activities and damming greatly impact OM transport, processing and deposition within river system (Ellis et al., 2012).

Rivers from tropical regions are important for carbon transport and deliver of >60% terrigenous OC to the world oceans (Meybeck, 1982; Ittekkot, 1988; Ludwig et al., 1996; Dagg et al., 2004). Studies highlighting the variability of OM compositions in tropical river systems are limited. Except the studies on large rivers such as Amazon (Hedges et al., 1986; Aufdenkampe et al., 2007), Kapus (Loh et al., 2012), Mekong (Ellis et al., 2012) and Congo (Spencer et al., 2012). OM studies in Indian rivers have been documented by Ittekkot and Laane (1991) and Ittekkot and Zhang (1989). In recent years compositional changes of OM in tropical rivers of India have become an important issue in view of increasing human pressure (damming and over agriculture) and the variability in the South West Monsoon (SWM). Monsoon rain feeding the Godavari river system in peninsular India, which is the second most important source after Himalayan Rivers (Ganges and Brahmaputra) of the annual freshwater discharge to the Bay of Bengal (BOB) from Indian subcontinent. Reduced monsoon rainfall and increased damming in the Godavari basin have not only enhance the rate of reduction in sediment load (1.4×10^6 ton yr^{-1}; Panda et al.,

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2011) but also cause biogeochemical changes within the river and estuarine systems (Sarma et al., 2009). The OM composition in the Godavari river basin depends on water chemistry, microbial population and natural sedimentation processes (Gupta et al., 1997).

In this study we report on the change in OM composition within the Godavari river basin under extreme climatic variability (i.e. reduced SWM) and various anthropogenic activities (excessive agricultural land use and damming). Organic geochemical tools such as elemental and, isotopic ratios, and biomarker approach were used to identify the nature of OM and their sources in total suspended matter (TSM) and sediments from the Godavari river basin during the SWM period of 2009.

2. Study area

The Godavari river is the largest monsoon fed river basin of India with its source at an elevation of 1065 m in the Western Ghat (Sahyadris). It travels 1465 km in SE direction before entering the BOB. The total catchment area is 0.3×10^6 km^2 ($\sim$9.5% of the geographical area of India) populated by of 75.3 million people ($\sim$6.5% population of India). The tributaries Pravara, Manjira and Maner in the right bank occupy 16% of the catchment area whereas the tributaries Purna, Panhita, Indravati and Sabri in left bank occupy 60% of the catchment area. The basin experiences a semi-arid to monsoonal climate with average rainfall of 0.003 mm km^{-2} yr^{-1}. Major part of the annual rainfall (84%) occurs during the SWM period (June–September) and periodic cyclonic storms often cause high rainfall ($\sim$88%) in the lower catchment of the Godavari river (CPCB, 1995). The whole basin is mainly covered with agriculture land (0.2×10^6 km^2) followed by forest land (0.09×10^6 km^2). A patch of coal belt is spread over the lower part of basin (0.01×10^6 km^2) covering the lower mainstream and a major part of the lower tributaries (Fig. 1).

Construction of dams over Godavari basin have been increased in numbers since 1965 and at present 300 hydrologic projects (various sizes) are operated regulating the total fluvial load transport to the BOB. The average surface runoff potential of the basin is 110.5×10^{12} L yr^{-1} from which 31.3×10^{12} L yr^{-1} is stored in the dam basins (CWC, 2010). Based on the water utilization the whole basin is classified into four parts, the upper reaches (from the source to the Manjira tributary), the middle reaches (from Manjira to the Pranahita and Indravati tributaries), the lower reaches (from Indravati up to the Rajahmundry) and the deltaic region (from Rajahmundry to the sea; Fig. 1).

3. Materials and methods

3.1. Data source and sampling

Monthly rainfall data from selected gauge stations in the Godavari basin were obtained from the Indian Meteorological Department (IMD). Water runoff at the terminal site (Polavaram) was obtained from the long term dataset (1965–2010) of the Central Water Commission, India (CWC). Annual water runoff and sediment load at selected gauge stations were calculated from the 20 year (1990–2010) dataset (CWC, 2005; 2007; 2009; 2010; 2012).

Fifty-six samples (35 sediments and 21 TSM samples) were collected from the Godavari mainstream and tributaries during the SWM of 2009. Agricultural land soils representing the major vegetation in the catchment were sampled along the mainstream. Agricultural and forest plant samples were collected according to their area of dominance along the river basin. For TSM samplings, 5–10 L of surface water were collected in acid cleaned jars and kept undisturbed for 48 h in the field laboratory for settling. The supernatant water was siphoned off and 50 ml was centrifuged at 1000 rpm (rotations per minute) for 5 min to collect the residue (Gupta et al., 1997). Sediment samples were collected using a van Veen grab (15×15 cm) and stored at $\sim$4 °C until analysis. TSM and sediments were freeze dried and homogeneously grinded prior to isotopic analysis.

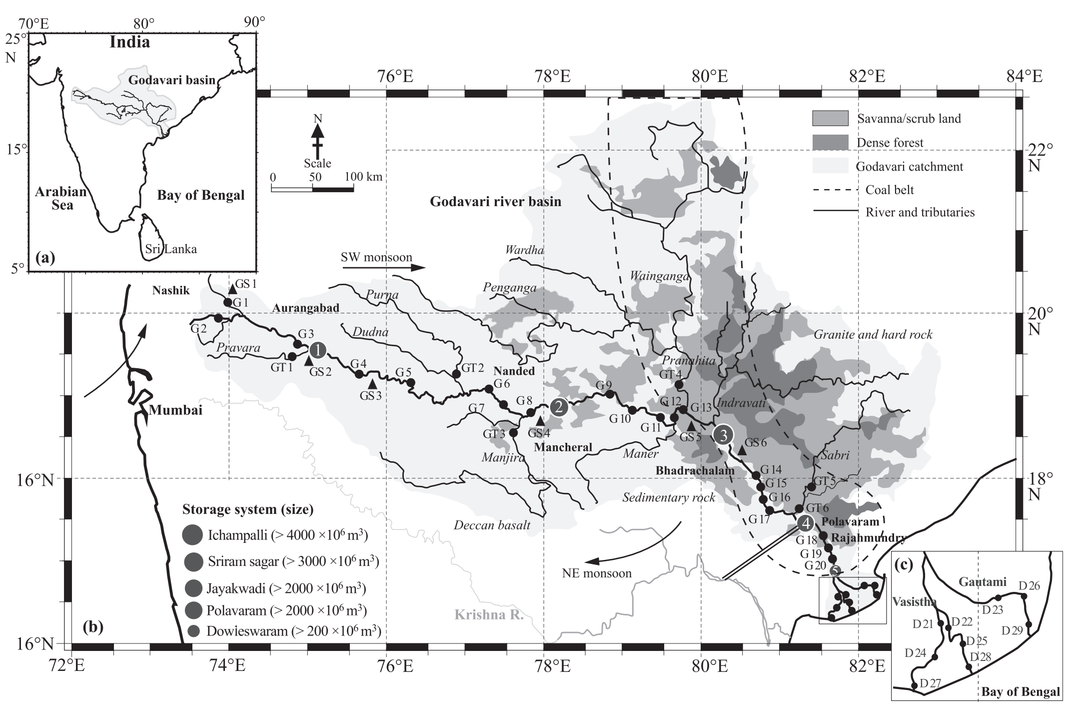

Fig. 1. (a) Location of Godavari river basin in the tropical (central-peninsular) India, (b) location of sampling sites along the river basin. Solid circles represent riverine samples (sediment and TSM) and triangles indicated the agriculture soil samples. Dotted black line indicates coverage of coal mining areas. Black circles with numeric inside indicate the position of the dams and their respective water volumes have been mentioned below. The directions of the SW and NE monsoon have been indicated by arrow marks (source: www.imd.gov.in). A Solid double line indicated the proposed canal (175 km) joining the Godavari and Krishna River.