RiOMar

Chapter 5: Anthropogenic Effects

Since the beginning of civilization, river systems have been altered as a result of human activities. An extensive review and comprehensive evaluation of anthropogenic impacts on river-ocean systems is beyond the scope of this workshop document. However, this brief overview highlights some of the perturbations of natural river-ocean systems that affect the fate of carbon and bio-relevant materials in RiOMar environments. Almost all modern observations of these environments include some aspect of human alterations. Over the past 300 years, a fundamental change in the Earth's surface conditions has occurred as a result of human influences. Human population during this period has increased tenfold and the perturbations resulting from human activities have greatly influenced biogeochemical cycles on Earth (Crutzen, 2002). The term "Anthropocene" has been used to identify this most recent period in geologic history (Crutzen and Stoermer, 2000). The period of most profound human impacts began ~ 1950, with dramatic increases in land use changes, dam construction, urban development, fossil fuel CO_2 input and fertilizer use (Meybeck, 2001). By 2025, approximately 75% of the world's population will live in the coastal zone (Postel et al., 1996). An additional (and significant) fraction of the population will live in inland areas adjacent to major rivers (Serageldin, 1995). This will undoubtedly result in increased human influences on RiOMar systems.

Most changes in riverine flux trends during the past 50 years can be attributed to human pressures. During the past 300 years, human activities on land have enhanced the loss of mass from the terrestrial organic matter reservoirs, mainly through deforestation and consequently have increased organic matter transport to the coastal margins by rivers (Ver et al. 1999). This impact of human activities on riverine organic matter fluxes to the ocean has not been well quantified. Smith and Hollibaugh (1993) estimate that present POM fluxes are double the natural (preindustrial) flux, whereas DOC fluxes have remained relatively constant. Rabouille et al. (2001) conclude that the increase in total organic matter flux from rivers has been approximately 50-70%. Direct measurements of organic matter fluxes in rivers have only been documented for the past few decades, a period too short to accurately resolve this issue. However, it is clear that many human-induced perturbations within the drainage basin (of which documentation extends beyond the past century in some cases) can have profound effects on riverine organic carbon fluxes.

The particulate load carried by rivers has been markedly altered by human activity, and may have doubled over the past few thousand years, only to be reduced in the past century by the widespread construction of dams (Meade et al., 1990). Human activities such as farming, timber harvesting, mining and urbanization have increased sediment loads to rivers. These increases have been modulated (during the past 50 years) by the construction of dams and reservoirs, which trap sediment before it reaches the ocean. Today, more than 23% of global river flow is dammed or diverted, and the water storage volume in reservoirs is now 7 times the volume of natural rivers (Vorosmarty et al., 1997). As a result, the average residence time of river waters has increased by a factor of 3 (Covich, 1993). Impoundments have changed the characteristics of rivers by altering temperature, stratification, turbulence, turbidity, redox conditions, and in situ production

(Friedl and Wuest, 2002). The hydrological regimes of rivers (volume and timing of peak flow) have also been altered. The construction of dams and reservoirs has undoubtedly played a major role in developing vast terrestrial carbon storage over the past 50 years (Stallard, 1998). Together, these changes have had an impact on the natural biogeochemical cycles of carbon and bio-relevant materials in river systems.

Natural sources of dissolved inorganic nutrients in rivers, largely mineral weathering and decomposition of terrestrial plants, have been augmented in many rivers by anthropogenic inputs including fertilizer use, leguminous crop fixation of nitrogen, urban run-off, and industrial and sewage discharges (Howarth et al., 1996; Jickells, 1998; Socolow, 1999). These inputs and the subsequent transformations within drainage basins have led to increases in the magnitude as well as changes in the elemental ratios of nutrient inputs in many river systems. Riverine inputs of N and P to the oceans have possibly increased by a factor of 2 to 3 as a result of human activities (Howarth et al. 1996, Jickells, 1998). This increase is primarily due to fertilizer use and direct discharges. The increased damming of rivers over the past 50 years has led to a decrease in P fluxes in recent years, as a result of particulate P retention (Jickells, 1998). Substantial deceases in dissolved silicate fluxes from rivers have been observed over the past 20 years, attributed largely to retention by dam and reservoirs (Humborg et al., 2000). In addition, Humborg et al. (2002) argue that the construction of large reservoirs in upland areas can lead to reduced weathering rates in these areas and reduced riverine dissolved silicate supply to rivers.

Increased riverine nitrogen inputs to coastal margins, coupled with decreased sediment inputs (decreased light limitation), have led to increases in primary production in river-ocean environments. The increase in riverine inputs of N (and P) due to eutrophication and the decrease in Si inputs, due to retention, can affect the ratio of nutrients available to the phytoplankton community, thereby altering the food web of RiOMar environments (Turner et al., 1998). For example, the frequency of diatom blooms has decreased and dinoflagellates and gelatinous species have become more important offshore of the Danube river (Humborg et al., 1997). Diatoms play a critical role in the sequestration of CO_2 from the atmosphere via the "biological pump" (Dugdale et al., 1995). Changes in nutrient ratios in RiOMar environments can also favor the growth of toxic algae, as evidenced by the increase in the frequency and severity of harmful algal blooms over the past few decades (Smayda, 1990).

During the past three centuries, there has been a significant increase in the amount of organic carbon transported from land and stored in coastal zone sediments, due primarily to fossil fuel CO_2 emissions to the atmosphere, changes in land-use practices, and sewage discharges. In addition, increases in the riverine inputs of nutrients (nitrogen and phosphorus) from land may be driving the trophic state of associated coastal zones toward net production and storage (autotrophy), thereby increasing the potential role of river-ocean margins as a sink for atmospheric CO_2 (Ver et al., 1999). The direction of future change in net ecosystem production in the coastal zone strongly depends on changes in the relative magnitudes of organic carbon and nutrient fluxes to the coastal zone via rivers (Mackenzie et al., 1998). The ultimate fate of organic carbon in river-ocean margins (burial or export) strongly depends on the biogeochemical response to changes in riverine input, which are driven by human alterations within the drainage basin.

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