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River export of multiple pollutants to the Bay of Bengal: past, present and future trends

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Rivers often contain more than one pollutant, causing multiple impacts such as eutrophication and fish kills. We analyzed water quality of rivers draining into the Bay of Bengal for 2000, 2010 and 2050. We focused on the following multiple pollutants in rivers: dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorus (DIP), micro-plastic and triclosan. We analyzed the pollutants in rivers from point sources that are associated with human waste: open defecation (for DIN, DIP) and sewage systems (for DIN, DIP, triclosan and micro-plastic). We quantified trends in river exports of the pollutants to the Bay of Bengal by integrating existing modelling approaches for individual pollutants with the sub-basin scale modelling approach of the MARINA model (Model to Assess River Inputs of Nutrient to seAs).

The results indicate that rivers of the Bay of Bengal were more polluted from point sources in 2010 than in 2000. River export of DIN and DIP from point sources increased by a factor of 1.2-1.6 between 2000 and 2010. River export of triclosan and micro-plastic from point sources increased by a factor of 1-1.3 during this period. These increases are associated with increased inputs of the pollutants to rivers from point sources. In 2000, almost all rivers received DIN and DIP from open defecation. Triclosan and micro-plastic were from sewage. In 2010, most rivers of India received DIN, DIP, triclosan and micro-plastic from sewage systems whereas the rivers of Bangladesh and Myanmar continued receiving DIN and DIP from open defecation. This indicates that India improved sanitation by introducing sewage systems to avoid open defecation. However, the treatment efficiency of removing pollutants in wastewater treatment plants was not sufficient enough to avoid an increase in inputs of the pollutants to rivers. Point sources were the dominant sources for the Ganges River and some Indian rivers such as Damodar and Cauweri.

Future trends in the river export of the pollutants are based on a SSP1 scenario (Shared Socio-economic Pathway). SSP1 assumes a future with more sustainable development by improving education and sanitation systems. We developed two alternative scenarios based on SSP1 for 2050: with poor (S1) and improved (S2) treatment of pollutants in sewage. In both an alternative scenario, open defecation is assumed to be zero and at least 75% of the population will be connected to sewage systems. River export of DIN, DIP, triclosan and micro-plastic is projected to increase by a factor of 1.5-9 between 2010 and 2050 in S1. In S2, rivers export of DIN and DIP is 70% lower in 2050 than in 2010. However, river export of micro-plastic and triclosan is still higher in 2050 than in 2010 despite an improved treatment in S2. Our results facilitate formulation of effective policies to increase water quality in rivers of the Bay of Bengal. Future studies should focus on including the non-point sources of pollutants in rivers.