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Impact of interaction processes on plastic dynamics in global major rivers

DR. TADANOBU NAKAYAMA, PHD
National Institute for Environmental Studies

Recent research pointed out inland waters act as important transport pathway for both water and dissolved substances and play significant role in continental biogeochemical cycling (Battin et al., 2009). In particular, contamination of plastic materials has received more attention during the last few decades (Kooi et al., 2018). Some models succeeded to simulate transport and fate of plastic debris in freshwater systems (Meijer et al., 2021), but a complete model is under development to elucidate the whole picture of plastic dynamics in continental scale. The author has developed a process-based eco-hydrology model, NICE (National Integrated Catchment-based Eco-hydrology) (Nakayama and Watanabe, 2004), and applied it to various basins. NICE can simulate iteratively nonlinear interactions between hydrologic, geomorphic, and ecological processes (Nakayama, 2020). Recently, this model was extended to biogeochemical cycle in terrestrial-aquatic-estuarine continuum (Nakayama, 2023), and to couple with plastic debris model (Nakayama and Osako, 2023, 2024).

In this study, the author extended NICE to model plastic dynamics and their relation to biogeochemical cycles in global major rivers. The model could simulate different speciation states of micro-plastic to indicate the impact of interaction processes of heteroaggregation (with suspended particulate matter) (Praetorius et al., 2012) and biofouling (with algae and phytoplankton) (Kooi et al., 2017) on plastic dynamics. In particular, the model could estimate attached algal growth as the function of encounter kernel rate. Result showed micro-plastic might quickly aggregate with suspended particle matter to form heteroaggregates in rivers with large amounts of micro-plastics, and this dominance of heteroaggregates is closely related to the higher concentration of suspended particles there. Further, the dynamic rate for biofouling simulated by the model found the algal growth affects diurnal and seasonal fluctuations of different speciation states of micro-plastic in some rivers, and the proportion of biofouled plastic increases in waters where the flow is slower and the retention time is longer. Finaly, global plastic budget was estimated by including storages of reservoir, lake, riverbed, estuary, and interaction processes. These findings provide valuable insights for improvement of plastic cycle associated with carbon cycle variations to minimize the range of uncertainty in inland waters.