The MARINA-Plastic model: Global river export of macro- and microplastics from over 10,000 sub-basins to coastal seas

Maryna Strokal¹, Paul Vriend², Jikke van Wijnen³, Carolien Kroeze⁴, and Tim van Emmerik⁵

¹Wageningen University, Water Systems and Global Change group, Wageningen, the Netherlands (maryna.strokal@wur.nl)
²Wageningen University, Water Systems and Global Change group, and Hydrology and Quantitative Water Management group, Wageningen, the Netherlands (paul.vriend@wur.nl)
³Open University, Department of Environmental Sciences, Faculty of Science, Heerlen, the Netherlands (jikke.vanWijnen@ou.nl)
⁴Wageningen University, Water Systems and Global Change group, Wageningen, the Netherlands (carolien.kroeze@wur.nl)
⁵Wageningen University, Hydrology and Quantitative Water Management group, Wageningen, the Netherlands (tim.vanemmerik@wur.nl)

Plastics are found in different sizes in many rivers and coastal waters worldwide. Our understanding of the sources of this plastic is poor. Quantitative, and spatially explicit data on plastic loads is needed to design effective plastic pollution reduction strategies. One way to gather such data is through modeling studies. To this end, we develop the MARINA-Plastic model for macro- and microplastic. The MARINA-Plastic model quantifies annual river export of macro- and microplastic by source from sub-basins to coastal waters of the world. The model runs for over 10,000 sub-basins and considers point (e.g., sewage systems) and diffuse (e.g., mismanaged solid waste on land) sources of plastics in rivers. We evaluate and validate the model using a “building trust” approach. Evaluation results indicate the robustness of the model performance.

Results of the MARINA-Plastic model show that approximately 10% of all sub-basins are, today, responsible for over 90% of macroplastic inputs to rivers globally. Asia and Africa are responsible for approximately 80% of the plastic export by rivers globally. Coastal waters of Asia and Africa are predominantly polluted with macroplastics from diffuse sources in terms of mass, whereas coastal waters of Europe and North America are predominantly polluted with microplastics from point sources. Middle- and downstream activities contribute largely to coastal water pollution with plastics for selected case studies. These case studies are six large rivers, of which the drainage areas are divided into up-, middle- and downstream sub-basins. These rivers are the Mississippi (North America), Amazon (South America), Danube (Europe), Niger (Africa), Nile (Africa), and the Yangtze (Asia) rivers. Our analysis shows that reducing plastic pollution in coastal waters requires improvement of the wastewater treatment in Europe and North America and solid waste management in Asia and Africa.

We show that the MARINA-Plastic model is applicable to get a better understanding of the sources and the spatial variability of the plastic pollution in rivers and coastal waters. The model allows to analyse the impact of upstream activities on downstream plastic pollution and to explore effects
of environmental policies on plastics in waters. This information can help to develop effective solutions for reducing future plastic pollution.