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# Assessing litter loads and estimating macroplastic emission rates of three major North Sea tributaries – Ems, Weser, and Elbe – through holistic, field-based observations

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Research into the scope of litter pollution, particularly of plastic debris, in freshwater systems has shown similar levels to the marine and coastal environment. Global model estimates of riverine emission rates of plastic litter are however largely based on microplastic studies as long-term and holistic observations of riverine macroplastics are still scarce. Our study therefore aimed to contribute a detailed assessment of macrolitter in the transitional waters of three major North Sea tributaries: Ems, Weser, and Elbe. It was hypothesised that the larger and more intensely used, the more polluted the river would be. Litter surveys were carried out in four river compartments: along the embankment, on the river surface, in the water column, and on the river bed. Plastic generally comprised 88-100 % of all recorded debris items. Our data revealed spatio-temporal variability and distinct pollution levels for each compartment. Beaches had the highest debris diversity and were significantly more littered than vegetated sites and harbours. Stony embankments were least polluted. Benthic litter levels appeared substantial despite rapid burial of objects being likely due to high suspended sediment loads. Extrapolated to daily mean emission rates, more plastic litter is discharged into each estuary via the river surface than through the water column. Combining both, the Ems emits over 700 macroplastic items daily, the Weser more than 2,700, and the Elbe ~196,000 objects. Using the mean (median) plastic item mass recorded from water column samples, i.e. 6.3 g (1.7 g), this equates to ~4.5 (1.2) kg $d^{-1}$ and ~1.6 (0.4) t $y^{-1}$ of plastic waste discharged by the Ems, ~17.2 (4.6) kg $d^{-1}$ and ~6.3 (1.7) t $y^{-1}$ for the Weser, and ~1.2 (0.3) t $d^{-1}$ respectively ~451 (122) t $y^{-1}$ carried into the North Sea via the Elbe. These rates deviate considerably from previous model estimates of plastic loads discharged by said rivers. Future studies should therefore ground-truth model estimates with more river-specific and long-term field observations, which will ultimately help assess the effectiveness of waste management and reduction strategies inland and on water.