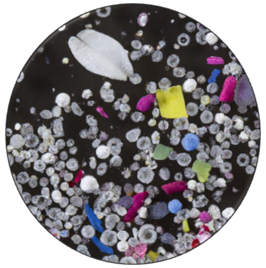
UNESCO-IWRA ONLINE CONFERENCE
17-19 JANUARY 2023
3rd IN THE IWRA ONLINE CONFERENCE SERIES

Modelling of microplastics in terrestrial waterbodies: advantages, drawbacks, and advancements

Emerging Pollutants: Protecting Water Quality for the Health of People and the Environment

Introduction

Plastic has become an integral part of modern society, with its production increasing rapidly from 2 million tonnes in 1950 to 368 million tonnes in 2019 (Plastics Europe, 2020). However, the majority of plastic produced has not been properly disposed of, leading to significant environmental pollution. The United Nations Environment Programme estimates that there are currently between 75 million and 199 million tonnes of plastic in the oceans, making up 85% of all marine litter (Jacqueline et al., 2021). Mathematical models can be used to study the movement and concentration of microplastics in rivers and their surrounding areas (catchments). These models can help researchers understand how microplastics are transported along river systems, how much is stored in riverbed sediments, and how much is transported into estuaries and marine ecosystems. However, since there are limited number of modeling studies on the transport and fate of microplastics in terrestrial waters, there are flaws and/or features that need to be improved in the modeling techniques applied. Within the scope of this study, microplastic modeling studies in the literature in the last 5 years were examined and it was aimed to evaluate them from the mentioned aspects.



Source Paper	Modeling Method	Advantages	Drawbacks	Applied media	Details
Li et al., 2022	Statistical mass balance model for flux estimation with cubic spline interpolation method.	• Easy to develop (less data required), • Simpler and flexible • high performance on site specific studies, • require less amount of computational time • more smoother curves with more accurate than lagrange interpolation	• Only takes MP abundance and daily runoff parameters into consideration • Statistical model, complex systems cannot be represented. • Cubic spline interpolation method may produce overfitting or oscillations for noisy or poorly distributed data.	Yangtze River, China	
Whitehead et al., 2022	INCA Sediment model; semi-distributed process-based eulerian mass balance model with Finite Volume Method (FVM) solution technique used for evaluate the impacts of microplastics on river water quality from effluent discharges&sewage sludge applications to agricultural land.	• physically based, • requires relatively little data compared to other sediment transport models, • has a user-friendly interface • can simulate range of physical&chemcal processes	• not suitable for highly nonlinear or small-scale features, • The accuracy depends on the quality and accuracy of the input data • effected by the choice of elements and time steps.	Thames River, UK	
Bondelind et al., 2020	3-D mass balance-based water quality model coupled with eulerian hydrodynamic model (MIKE 3 FM ECO Lab) with Finite Element Method (FEM), used to study the fate and transport of traffic-related MP released with stormwater.	• flexible and adaptable computational mesh, • physically based, • advection-dispersion&settling are both considered, • can simulate range of physical&chemcal processes • Coupling capability with other MIKE modules.	• Requires relatively high computational time, • requires a high level of expertise and a large amount of input data, • effected by the choice of size of elements and time steps.	Göta River (more like to estuary), Sweden	
Daily and Hoffman, 2020	3-D Lagrangian advection&vertical diffusion distributed FVCOM based model, with 4th order Runge-Kutta to investigate the impact of vertical movement on transporting plastic away from the surface and determine plastic deposition rate in the sediment and whole lake mass estimate.	• Model has been previously used for same purpose, • flexible and adaptable model, • physically based, • has a robust and active user community	• Does not take resuspension into account, • can be computationally intensive, • requires a high level of expertise and large input data • not suitable for highly nonlinear or small-scale features	Lake Erie, US	
Ma and You, 2021	3D – Ecotracer pollutant module of Ecopath Eulerian model, with Finite Difference Method (FDM) solution technique used to investigate the influence of rainfall on the abundance of MPs in aquatic environments, including the variation of MPs in water and aquatic organisms, the mechanisms of transfer and accumulation among various trophic levels, and the enrichment of MPs through the foodweb.	• Flexible and customizable model, • Physically based, • Easy to use • Ecological culture and transport are considered well • Up to 3-D simulations can be conducted. • Be used conjunctively with a hydrodynamic model	• Only considers steady-state condition • Based on mass balance of functional groups, thus not includes all biogeochemical mechanisms • Requires a large amount of input data • can be computationally intensive • not suitable for highly nonlinear or small-scale features	Baiyangdian Lake, China	
He et al., 2021	3D – TUFLOW Finite Volume (TUFLOW FV) Eulerian hydrodynamic Model, with finite volume solution technique used to model microplastics in river sediments	• Flexible and customizable model, • Easy to use • can simulate wide range of physical&chemical processes • both have structural and unstructural control volumes (complex geometries handling is well)	• Requires a large amount of input data • Can be computationally intensive • representation of complex system can be problem due to number of assumptions and simplifications • not suitable for highly nonlinear or small-scale features	Brisbane River, Australia	
Mason et al., 2020	2D – lagrangian hydrodynamic Finite Volume Community Ocean Model (FVCOM) used to compare results from a Lagrangian transport model of Lake Erie with a previously unpublished multi-year surface sample set	• flexible and adaptable model • Unstructured grids smoothly fit to the shoreline, • requires less computational time (only advection), • has a robust and active user community	• Diffusion mechanism is not taken into consideration for this study, • can be computationally intensive, • requires a level of expertise and large input data, • not suitable for highly nonlinear or small-scale features	Lakes Erie and Ontario, US	

Methodology

- Within the scope of the study, research articles published in the Web of Science Core Collection database and published in the period of 2017-2022 were compiled. The search process was carried out using the topic keyword of "microplastic modeling" and title keywords of "river" and "lake". A total of 19 research papers have been gathered.
- It has been detected that among those 19 papers only 7 are modeling studies, the rest were studies about the transport mechanisms such as settling, aggregation, adsorption, biofouling etc. which will be useful for modeling studies in a long term.
- Their mechanisms and modeling techniques are evaluated in terms of the advantages and drawbacks.

Results&Conclusion

There is still a lack of sufficient applications of microplastics in terrestrial water masses. Although rivers have been studied less than lakes, there are more studies on sediment transport in rivers than on water mass transport. In particular, the absence of a standard method that is widely accepted for microplastic analysis undermines the comparability of the studies. There are no modeling studies that can simultaneously simulate the mechanisms of microplastics (settling, resuspension, uptake by microorganisms and plant roots, biofouling, etc.). Detailed studies are needed on these topics.

Acknowledgment

This study was supported by TÜBİTAK project number 121Y460.

Yiğithan Kazancı*, Orhan Gündüz, Neval Baycan
*Reserach Assistant&Izmir Institute of Technology

unesco
Programme hydrologique intergouvernemental

Li et al., 2022

This study found that the Yangtze River transports a large amount of microplastics to the East China Sea, with an estimated total of 7020 metric tons transported in 2020. The main sources of these microplastics were tributaries (62.9%), non-point sources such as vehicle trips (34.2%), and point sources (2.9%). The majority of the microplastics were transported in the middle section of the river, accounting for 55.56% of the total.

Whitehead et al., 2022

This study found that there is a significant amount of microplastics being flushed down a river system and into the Thames estuary, with a total load of 100 tonnes per year. The study also found that a significant portion of this pollution can be prevented by controlling the pathways of the microplastics, such as through the control of effluents from wastewater treatment plants and the application of sludge to land. The study was able to decrease the amount of microplastics by 50% through these efforts.

Bondelind et al., 2020

The study found that the concentration of microplastics (MP) in a river was influenced by factors such as stormwater discharge points, catchment area pollution, and the vertical water density gradient caused by intruding saline water. Larger and heavier MP particles tended to settle in the river, while smaller particles did not settle and reached the Kattegat Strait.

Daily and Hoffman, 2020

A model that covers approximately 75% of polymer types found in plastic waste overpredicted the amount of particles at the surface and underpredicted the amount deposited in sediment. Despite being called sinking polymers, some were found at the surface due to turbulent mixing. The sediment deposition rate was estimated to be 170.8 ± 79.4 metric tons per half year.

Ma and You, 2021

This study found that the abundance of microplastics (MPs) in aquatic environments and organisms showed periodic changes with rainfall intensity, peaking in the summer each year. The accumulation of MPs in aquatic organisms was found to vary, with the highest trophic level (snakehead) showing the highest accumulation at 3.97 times the initial abundance. The study also found that the abundance of MPs accumulates through the food web and can have negative impacts on human health, suggesting the need for greater attention to the accumulation of MPs in human bodies and ecosystems.

He et al., 2021

The transport of simulated microplastic particles in a river was found to be influenced by flow velocity in the bottom layer and the tidal input from the ocean. Results showed that microplastics with lower densities (such as PE and PP) had higher mobility, while higher density microplastics (such as PA and PET) were more prone to be retained in river sediments, particularly in areas near the source or where there was a drop in water flow energy. Overall, the study found that river sediments can serve as a retention mechanism for various types of microplastics.

Mason et al., 2020

A study of Lakes Erie and Ontario found that plastic abundances varied from approximately 1400 to over 1.3 million particles per km2, with higher abundances generally found in the eastern and central basins and along the southern shoreline. Polyethylene (46%) and polypropylene (43%) were the most common types of plastic found, with high-density polyethylene being more prevalent. Modeling studies indicated that the dynamics of Lake Erie led to a heterogeneous distribution of plastic particles after a year, with estimates ranging from 214 to 573 million particles floating in the nearshore or open water with a mass of 2.62 to 7.79 metric tons.