Introduction
Background:
- Microplastics may enter the environment from a number of sources and in many forms.
- Plastic particles may be present as influent into municipal wastewater treatment plants (WWTPs).
- A large portion of these are removed from the water phase during the treatment process, and generally end up in the solids (i.e., sludge).
- Sludge disposal varies by country, region and locality, including landfill, incinerator, compost, or as land-applied biosolids.
- There is potential for particles in biosolid applications to reach aquatic systems depending on application location and subsequent environmental conditions.

We present a broad-scale model designed to estimate emissions and model the fate of plastic particles exiting WWTPs into the terrestrial and aquatic environments
- using spatially-explicit information on WWTPs, river hydrology and terrestrial transport potential.
- This regional/continental scale model is based on publicly available datasets and in a modular framework which is scalable and portable to multiple geographies.

Conceptual Model
The model was designed to be global in extent but incorporate sufficient local processing to capture the geographic heterogeneity of usage, treatment and environmental factors.

The model captures household emissions to wastewater and accounts for handling of sludge containing microplastic particles.

A watershed containing 28 sub-basins with corresponding land cover and WWTP locations.

Movement from the Terrestrial Environment
Microplastics captured in sludge and applied to agricultural land via biosolids are modeled with the Pesticide Root Zone Model (PRZM) using 15 scenarios covering weather and soil characteristics. Scenarios were informed by a JRC dataset using RUSLE2015 to estimate soil loss in Europe utilizing rainfall erosivity, soil erodibility, cover management, topography, and support practices (Panagos et al, 2015). Within each of the three defined EFSA zones, a geometric binning approach was used to identify 5 bins (0-50t, 51-75t, 76-87.5t, 87.6-93t, 94th-100th) in order to ensure inclusion of high erosion areas.

Biosolids application occurred twice a year to maize. One-half of the PRZM 30-year annual average % of applied mass leaving the field is conservatively assumed to occur twice a year. These aspects are configurable.

A "baseline" PEC is calculated excluding episodic events such as agricultural runoff. This represents the steady-state condition from continual WWTP effluent. Episodic events add additional mass (and water) to simulate a "peak" event.

In-River Settling Particle
Particles settle in the river based on particle size, river depth, and time of travel, using relationships from the NanoDUFLOW model (Besseling et al 2017). This incorporates processes such as homo-aggregation, hetero-aggregation with natural colloids, biofouling, settling and resuspension into a generalized net settling velocity.

Net settling velocities are configurable and can be related to waterbody type, river velocity, or other local/regional characteristics as available.

Analysis of Model Sensitivity to User Inputs, Model Data, and Simulation Processing

Results and Visualization
Results from an example model run using inputs below can be summarized and visualized in several methods, from tabular output, spatial mapping, or aggregation to different spatial levels or environmental compartments.

Environmental Concentrations

Model Features:
- Estimate environmental exposure of source microplastics entering WWTPs, including:
  - Variable consumer use rate
  - Variability in wastewater sludge handling practices
  - Terrestrial transport using environmental factors
  - Hydrologic routing using well-established datasets
  - Particle mass disposition within compartments
  - Spatially explicit: aggregation and examination
  - Scalable and extensible to other geographies

References: