Numerical modelling of plastic transport and accumulation at the Austrian Danube River

Pessenlehner, S.1,
Liedermann, M.1, Tritthart, M.1, Habersack, H.1

03.04.2019 – SedNet Conference, Dubrovnik

1 Institute of Hydraulic Engineering and River Research (IWA)
Department of Water, Atmosphere and Environment
University of Natural Resources and Life Sciences, Vienna, Austria
Email: sebastian.pessenlehner@boku.ac.at; Phone: +43 1 47654-81924
Introduction

• Worldwide plastic production increase: 1.7 Mio. t (1959) to 348 Mio. t (2017) (PlasticsEurope, 2018)

• Most important plastics: PP, PE, PS, PU, PET, PVC (PlasticsEurope, 2018)

• Total degradation of plastics in nature very slow

Source: PlasticsEurope 2018

Source: BBC, 2017
Introduction – Project area

- More than 80% of marine plastics is related to land-based sources.
- Rivers nowadays are known to be the main contributors for plastic debris to the ocean, but almost no studies in freshwater systems.
- Increasing quantities of macro plastic waste (particles > 5mm) near the banks and within the inundation areas of the Nationalpark Donau-Auen (collecting activities).
- Launching of a project to deal with macro plastic waste in and along the Danube between Vienna and Bratislava.
Aims of PlasticFreeDanube

- Methodologies, data and a manual for assessment and monitoring plastic pollution in the fluvial ecosystems
- Action plan for the management of plastic waste and implementation of pilot measures against plastic pollution in the Danube
- Awareness raising (public & stakeholders) about plastic litter pollution in rivers

Modelling and monitoring of plastic pollution in the fluvial ecosystems

- Detection of accumulation zones
- 3D Hydrodynamic Modelling
- Particle Tracing → Characterization of accumulation zones (bank near & inundation area)
- Possible construction ideas to reduce sampling actions
Methods

Detection / Characterisation of accumulation zones – Morphodynamics

Digital Terrain Models based on:

• Laser Scan 2010 / Single Beam 2015 / Terrestrial Survey 2006
Methods

Detection / Characterisation of accumulation zones – Flow field

- ADCP discharge & flow velocity
- GSP water level measurement

Calibration and validation

12 profiles
2 groyne fields
Tasks and Methods

Modelling of accumulation zones

• Hydrodynamic Modelling of the flow field
• Particle tracing in complexe structures
Accumulation Zones → Determination

Data from Excursions and waste collection campaigns of the “National Park Donauauen” used to determine modelling reaches → Gathered in a GIS map
Accumulation Zones → Modelling Areas

- 3D numerical model Haslau (2.5 km)
- 3D numerical model Wildungsmauer–Witzelsdorf (4.2 km)
- 2D large scale model Vienna–Bratislava (25.6 km)
Hydrodynamic Modelling

Setup of a hydrodynamic model of the accumulation zone Haslau

- Software: RSim-3D
- Hexagonal cells in several layers
- Different cell sizes according to river bed geometry
- Detailed evaluation of hydraulic structures
Numerical Model – 3D Model Haslau

Result RNQ: 980 m³/s
Numerical Model – 3D Model Haslau

Result MQ: 1930 m³/s
Numerical Model – 3D Model Haslau

Result Q: 3000 m³/s
Numerical Model – 3D Model Haslau

Detail – velocity vectors surface layer

Flow velocity [m/s]

- 0.300
- 0.600
- 0.900
- 1.200
- 1.500
- 1.800
- 2.100
- 2.400
- 2.700

RNQ: 980 m³/s

RNQ: 1930 m³/s

RNQ: 3000 m³/s
Numerical Models – 3D Model Haslau

Water age

980 m³/s

1930 m³/s

3000 m³/s
**Numerical Models – 3D Model Haslau**

Detail - Particle Tracing (2D) surface layer

980 m³/s

1930 m³/s

3000 m³/s
Conclusions – 3D Numerical Model Haslau

- Significant vortex formations and high water age at RNQ (980 m³/s)
  ➔ marginal macro plastic accumulation

- Scenario water level lowering to RNQ
  ➔ high probability of macro plastic accumulation

- Partial overflow of groynes and guiding walls at MQ (1930 m³/s)
  ➔ Moderate vortex formation; initial accumulation

- Entire overflow of groynes and guiding walls at 3.000 m³/s
  ➔ Remobilisation of macro plastic
Numerical Model – 2D Large Scale Model Vienna - Bratislava

- Evaluation of macro plastic transport in the inundation area
- Implemented concept model considering drainage effects
- Quasi-stationary discharge used for particle tracing

Software: RSim -2D
Numerical Model – 2D Large Scale model Vienna - Bratislava

Particle Tracing (2D) – Inundation area
2D Numerical Model

Characterisation of accumulation zones

- Bank near/shore line accumulation
  - occurring at frequent water levels
  - influenced by wave splash

Statistical analysis of hydrologic data
Numerical Model

Characterisation of accumulation zones

- Bank near/shore line accumulation
  - Classification of discharge periods based on 25% and 75% quartiles

### Danube 1977 - 2015

- **Discharge [m³/s]**
  - Winter: Jan, Feb, Mar
  - Spring and Summer: Apr, May, Jun
  - Autumn and Winter: Jul, Aug, Sep

- **Quartiles**
  - 25%
  - 75%
  - Median

**Autumn & Winter: Q1000 – Q2000**

**Spring & Summer: Q1450 – Q2850**
Numerical Model

Characterisation of accumulation zones

- Flood plain accumulation
  - starting from 2400 m³/s
  - quantification of partial discharge
  - effect of vegetation
Numerical Model

Characterisation of accumulation zones

- Flood plain accumulation
  - High accumulation potential related to specific discharge

Specific discharge (m³/m²) in the inundation area Haslau at Q6000 m³/s
Numerical Model

- Flood plain accumulation
  - High accumulation potential at the outflow area
  - Decreasing accumulation potential depending on the distance from the outflow caused by filtration effect of vegetation

Specific discharge / distance from inlet area
Conclusions – 2D Large Scale model Vienna - Bratislava

2D large scale model Wien-Bratislava

- Simulation of quasi-stationary discharge suitable for particle tracing
- Particles are likely to drift into side arms (connected from 2.400 m³/s)
- Accumulation of particles in sink areas of the floodplain during water level lowering can be observed
- Determination of bank near accumulation areas for 2 periods
- Characterization of flood plain accumulation with respect to vegetation effects (Validation)

Q = 2400 m³/s
Protect Nature – avoid pollution!