Coastal accumulation mapping of microplastic particles emitted from the Po River, Italy
Comparing remote sensing, in situ sample collections and ocean current modelling

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Sentinels4marine plastic waste Po delta project-specific collaborators
Rivers: a major source of marine plastic

• 4.8 - 12.7 mt plastic from land sources entered the oceans in 2010 (Jambeck et al., 2015)
  – Rivers release 1.2 – 2.4 mt annually (Lebreton et al., 2017)

• Mediterranean particularly highly impacted
  – Floating plastic accumulation 1,000 - 3,000 t (Cozar et al., 2015; Suaria et al., 2016)

• River plumes, together with rivers, deserve more research focus
Northern Adriatic Sea and Po Delta

- Prevailing currents: CCW along Balkans, return with Western Adriatic Current (WAC)
- Po largest freshwater influx, av. daily 1500 m$^3$/s, other large rivers < 17%
- Longest river in Italy
- N Adriatic circulation determined by freshwater influx and wind regime

Po Delta
- High biodiversity, especially birds, UNESCO World Heritage Site since 1999
- Aquaculture, fisheries, agriculture
- 5 main mouths, 2 side channels, shifting river mouth sandbars
Study overview

• Field sampling

• Comparison of two different models:
  – Hydrodynamic-Lagrangian
  – Remote sensing

• Comparison of model exposure maps

• Validation against in situ samples
Field data collection

- Field campaign conducted from June 4th-25th, 2016
  - Boat water sampling:
    - Sediment samples: dried, separated with zinc chloride (1.6–1.8 g/cm³), visually sorted 1–5 mm
  - Beach sediment sampling:
    - EHT transect (100 m)
    - 11 quadrats
    - Low to high pollution

- Microplastic identification
  - Water samples: enzymatic purification & wet peroxide oxidation size class fractionation
    - 5 mm – 500 µm → ATR FT-IR (Löder et al., 2015)
    - 500 – 300 µm → µFT-IR (Löder and Gerdts, 2015) and SWIR (Schmidt et al., in review)
  - Sediment samples: dried, separated with zinc chloride (1.6-1.8 g/cm³), visually sorted 1 – 5 mm → ATR FT-IR
Field microplastic measurements

➢ **Highest water** microplastic concentrations found along **outer edge of river plume**, within the main river section (Po della Pila) and Tramontana

➢ **Sediment concentrations** peaked for the two northernmost beaches **Caliere and Barricata**

➢ **PE, PP and styrene polymers** made up more than 97% of all sampled particles from most beaches
Hydrodynamic-Lagrangian (HD) model

- 1.5 year modelling period: January 2015 – June 2016
- Lagrangian model (ICHTHYOP) implemented together with forecasts from a state-of-the-art coupled ocean-waves hydrodynamical model (ROMS-based; Carniel et al., 2016)
- Virtual Microplastic Particles (VMP; 1 mm sphere, 0.91 g/mL) released from all five river mouths + Scirocco
- Daily release rate based on streamflow and concentration of 10 particle/m³
- VMP tracked for 60 days
- Considered beached if passing within 250 m of coastline (due to model grid resolution), smoothed coastline used to avoid “shadowing”
HD beaching and accumulation patterns

➢ High beaching rates semi-coupled with high river discharge events
➢ Beaching not only driven by the amount VMP released, surface currents also very important

➢ Of all VMP released, only 18% were found to beach
➢ Pila, Scirocco and Gnocca river mouths were found to beach less than 10% of VMP released
➢ Highest beaching determined for southernmost river mouth, Goro, with 94% beaching rate
➢ Highest accumulation areas were south of Pila, and near to Gnocca and Goro river mouths
Remote Sensing (RS) model

- SPM algorithm for Sentinel-2 and Landsat-8 images calibrated to system using *in situ* measurements, atmospheric correction with ACOLITE (L8) & Sen2Cor (S2)
RS model

• Modelling period January 2015 – June 2016, 26 images
• Masked land, clouds, boats, white caps and breaking waves

• Only pixels closest to coastline considered
• Coastline exposure defined as strength of river water signal in a coastal pixel -> similarity ratio using the average SPM concentration from all 5 river mouths for that acquisition date
• Data binned into hexagons and summed over entire time period
Model comparison and validation

➢ **Similar pattern**
  - High values for Pila, Tolle, Gnocca and Goro
  - Low values for northern coastline

➢ **Dissimilarities**
  - Maistra, Tramontana and Scirocco had strong RS signal but low HD signal

➢ **Numeric comparison**
  - Small positive bias for HD signal observed
  - Highest variation for Pila, Scirocco and northern to central Tolle mouths

➢ No significant relationship found comparing *in situ* beach sediment microplastic concentrations to the nearest hydrodynamic model grid cell ($p > 0.10$ for Pearson’s $r$ and Spearman’s $\rho$)

➢ Removal of locations under more influence from beach tourism and nearby aquaculture (Caleri, Levante, Boccasette and Barricata) resulted in a stronger correlation ($r = 0.79$ and $\rho = 0.80$, $p < 0.07$)

➢ Remote sensing model had no significant correlation
Conclusion and directions for future research

• Microplastic accumulation/exposure over 1.5 years along the Adriatic coastline was modelled using two different approaches: Lagrangian particle tracking sub-model, fed by modeled ocean currents, and remote sensing of sediment heavy river plume waters

• Comparison of model maps showed similar patterns, difficult to compare with *in situ* sampling

• Hydrodynamic approach revealed:
  − differing beaching rates between river mouths, especially southernmost Goro
  − particle beaching primarily within first 10 days
  − emitted particles that were moved offshore remained offshore

• Remote sensing approach revealed:
  − river mouth relative strength

• Model assimilation of RS data to continually correct hydrodynamic model a very powerful approach
Thank you and any questions?

References:
Schmidt, L.K., Bochow, M., Imhof, K.H., Oswald, S., in review. Multi-temporal surveys for microplastic particles enabled by a novel and fast application of SWIR imaging spectroscopy – Study of an urban watercourse traversing the city of Berlin, Germany. Environmental Pollution.

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Photo: S. Piehl
Hydrodynamic-Lagrangian model accumulation map

- Higher VMP beach accumulation locally around each river mouth, except for Goro, the southernmost river mouth
- Highest accumulation areas were south of Pila, and near to Gnocca and Goro river mouths
Remote sensing model exposure map

- Clear river water influence around all river mouths
- Strongest signal from Tramontana, Pila south and central Tolle arm
- The southern arm of Po delle Tolle was observed to have a lesser influence
- Area of very high river water influence detected between Pila and Tramontana, which corresponds to an additional river mouth flowing out from the lagoon that was first observed during the field campaign