Plastics and microplastics – A future marker to reconstruct floodplain chronology (Opinion) *EGU21-62*

Weber, Collin J.[*]; Lechthaler, Simone[+§]; Stauch, Georg[+] and Opp, Christian[*]

[*]Soil Geography and Hydrogeography, Soil and Water Ecosystems – MicroplasticLAB, Faculty of Geography, Philipps-University of Marburg, Germany
[+]Department of Geography, Chair of Physical Geography and Geoecology, RWTH Aachen University, Germany
[§]Institute of Hydraulic Engineering and Water Resource Management, RWTH Aachen University, Germany

Contact: collin.weber@geo.uni-marburg.de

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1. Plastics and microplastics in floodplains

- Plastics and microplastics (MPs) are **present in river systems**
- Regarding the „global plastic cycle“ – rivers act as main transport routes from land to sea

- From a **landscape perspective** rivers are always attended by floodplains
- Plastics and MPs are present in floodplain soils and sediments

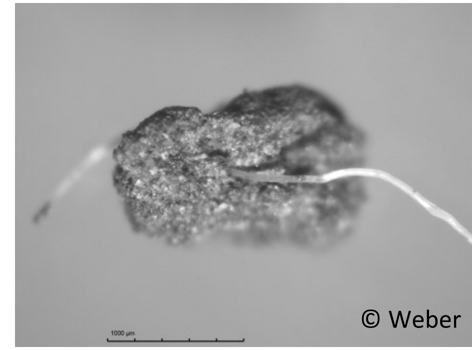
- Plastics can be **deposited within floodplain sediments** through overbank flows (floods)
- Further sources in floodplains are: Direct littering, land use (agriculture), …

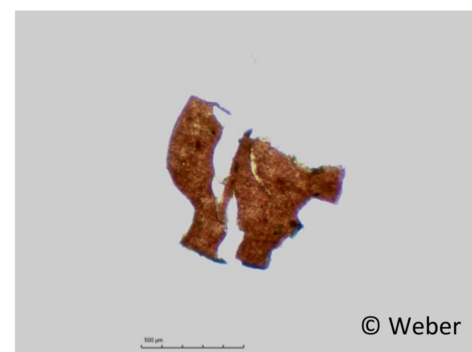
(Blettler et al., 2017; Lechthaler et al., 2021; Scheurer and Bigalke, 2018; Weber and Opp, 2020)

1. Plastics and microplastics in floodplains

- Plastic and especially microplastics are an **emerging threat** to fluvial and terrestrial ecosystems
- Plastics are purely **anthropogenic pollutants**, without natural (geogenic) background levels in sediments
- Plastics show **long residence times** in the environment (buried, half-live, partly modelled over > 2,500 years)
- Always **particles** (have shape, surface and are classified by size) and are traceable
- Plastics are distinguishable:
  Polymer types (e.g. PP or PET) can be determined by spectroscopic methods

(Chamas et al., 2020; Machado et al., 2018; Zalasiewicz et al., 2016)





2. Conventional floodplain chronology

General based on soil surveys and profile records (e.g., gravel pits) to access stratigraphic informations:

Selection of methods for compiling a chronology:

- Stratigraphic informations
- Grain size distribution
- Heavy metal analyses
- ^{14}C-Dating
- Luminescens dating (OSL)
- ^{210}Pb and ^{137}Cs

Partially cost- and time-consuming, equipment required, partially limited in the case of very juvenile recent sediments.

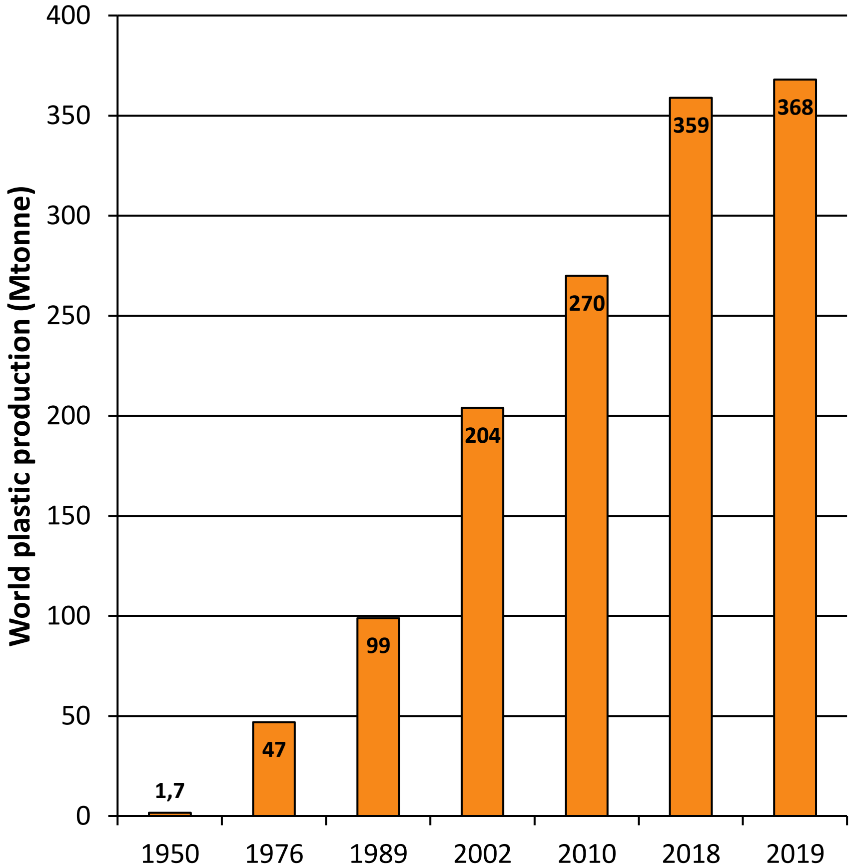
(Andersen, 2017; Appleby, 2001; Wysocki et al., 2005)

3. Plastics as a marker of floodplain chronology

Even if plastic is a pollutant in the environment - its occurrence and properties can be used to advantage!

Requirements for use as a marker:

- Findable and identifiable material (easy for macro- and mesoplastics: visual in the field)
- Anthropogenic material - no geogenic background content
- Clear chronological occurrence:
  a) In general: Exponential growth in plastic production (global) since the **1950s**
  b) Age of **earliest possible occurrence** (EPO age) for each polymer type



Growth of plastics production: from PlasticsEurope (2013, 2020).

3. Plastics as a marker of floodplain chronology

General marker (I) 1950

- Sediment containing plastics were very likely to be deposited after **1950**, as little plastic had previously been able to reach the environment
- Simple chronological distinction between young and old sediments

Specific marker (II) approx. 1910-1990

- Identified polymer type (e.g, PET, PE) through spectroscopic methods (e.g., ATR-FTIR) in sediments can be assigned to the EPO age
- EPO Age: Production starting year or patent (did not occur before!)
- Specific chronology can be set up on the basis of the particles occurring, their depth and the EPO age

Polymer	EPO[a]
resin	1910
PVC	1912
PS	1931
HDPE	1935
PA	1935
PUR	1937
PTFE	1941
ABS	1948
LDPE	1952
PP	1954
PET	1973
CSM	1990

[a]EPO year according to “History of Plastics” (British Plastic Federation, 2020) and / or “PLASTIKATLAS 2019” (Caterbow and Speranskaya, 2019).

3.1 Benefits

Plastics as a marker of floodplain chronolgy enables a mostly inexpensive and quick to implement alternative or additions to conventional methods!

In case of macro- or mesoplastics (> 25, > 5 mm):

- can be applied in the field (soil profile) - no analytics necessary (*see example pictures right*)
- Straightforward connection to the stratigraphy

In case of microplastics (< 5 mm)

- Method bundle of sample preparation, separation and identification necessary
- Can be used in studies that investigate microplastics anyway or as a supplement to conventional methods

Additional benefit!

3.2 Pitfalls and limitations

<u>**Remember**</u>**:**

Plastics and microplastics research is still in its infancy!

- Consideration as a marker only possible in connection to sediment/soil stratigraphy (not exempt from the profile documentation)
- Only applicable if particles are clearly covered by sediment (sedimentation) at undisturbed sites - otherwise also littering or other source possible
- Plastic especially microplastic can be displaced in the soil (bioturbation, preferential flow pathways) *(Rillig et al., 2017; Yu et al., 2019, Weber & Opp, 2020)*

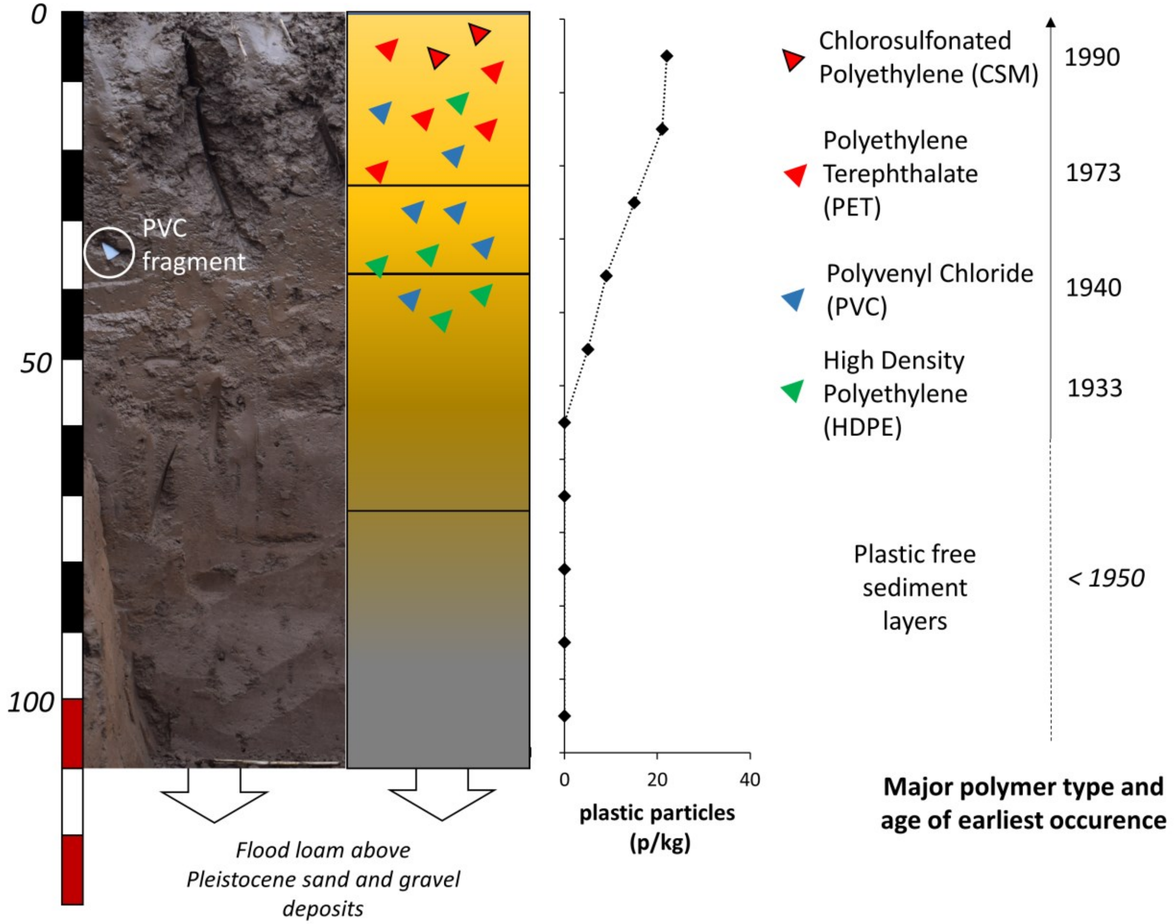
  Recommendation: Safer application if only particles of the macro, meso or coarse microplastic (CMP) size class (> 2 mm) are used. Advantage: Makes analytics easier!

- The EPO age only allows the distinction "cannot occur earlier" to "may occur earlier“ and may vary depending on the reference used (e.g., start of production or patent application)

4. Application examples

Ideal chronology based on plastics:

- Increase in plastic concentration, polymer types and ages in clear sequence, recent polymer types only at upper sediment layer
- Plastic free sediment layers deposited before the increase in plastic production (approx. 1950)



Weber et al. (2021) vPICO EGU

4. Application examples

Lechthaler et al. (2021):
https://doi.org/10.1039/D0EM00431F

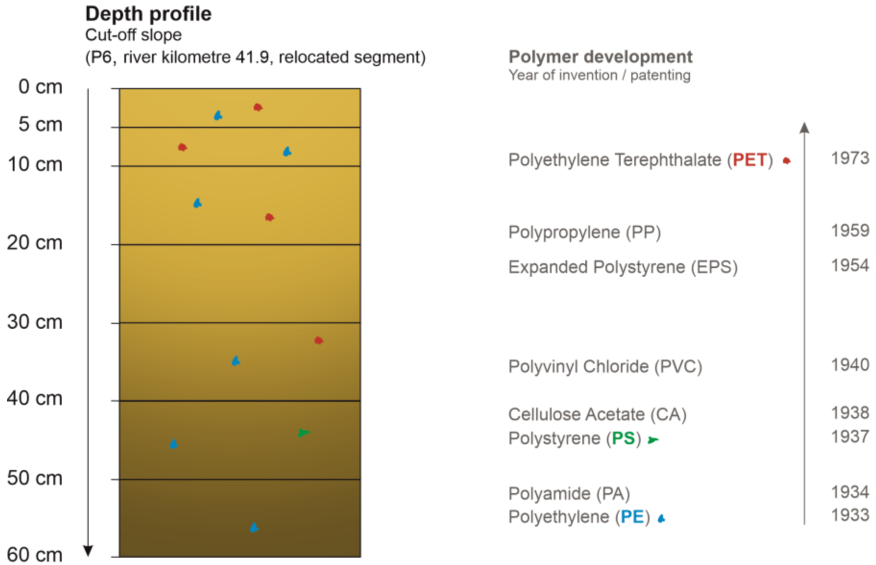
- Calculation of sedimentation rates $\boldsymbol{sr_{MP}}$ with MP detection by relating the sediment depth with detected MP to the reference period (1950 - 2020)

$$sr_{MP} = d_{MP} / t_{MP}$$

d_{MP} [cm]: Sediment depth containing MP
t_{MP} [a]: Reference period of MP (70 years)

sr_{MP}: 0.29 – 2.00 cm/a (Ø 0.8 cm/a)

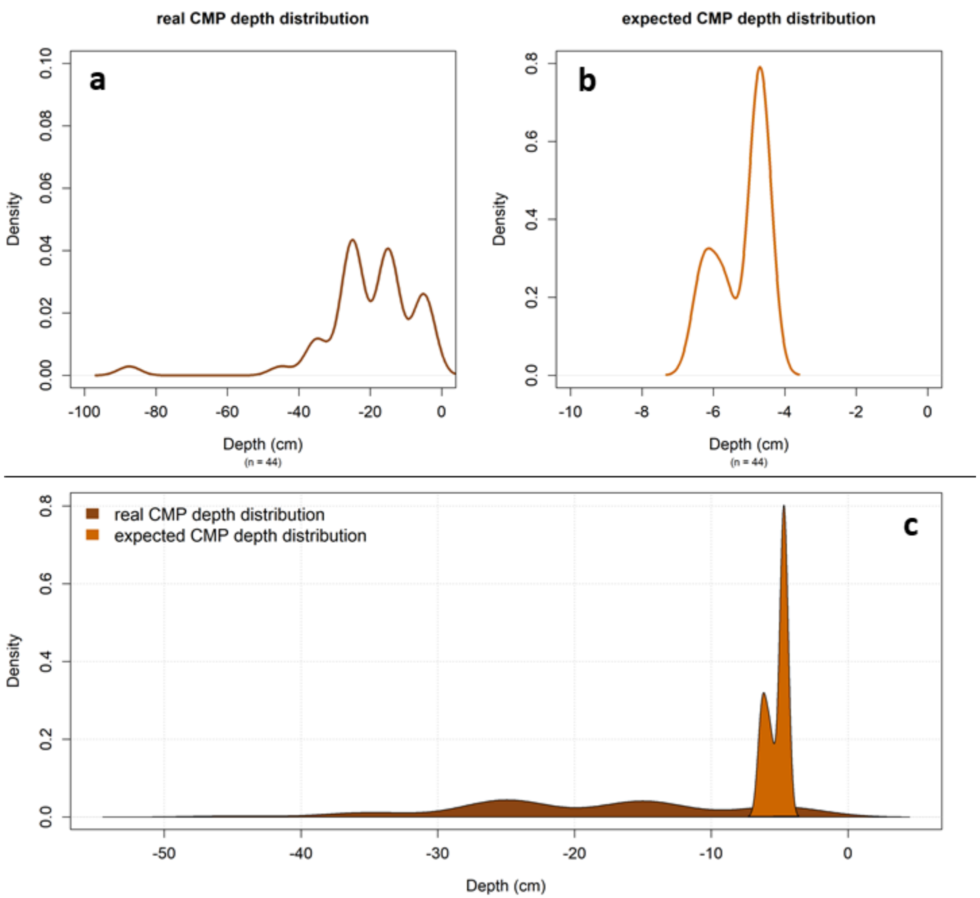
- First attempt for **correlation** within a floodplain depth profile:
  - MPs already accumulated up to a depth of 60 cm
  - the older the polymer (here PE) the deeper the sediment layers it was found in



4. Application examples

Weber & Opp (2020):
https://doi.org/10.1016/j.envpol.2020.115390

- Real and expected depth distribution of CMP (> 2mm) in floodplain soils
- Expected depth distribution based on EPO age and catchment sedimentation rates
- **Evidence:** Plastic is found deeper than it could be deposited via natural sedimentation. Indication of in-situ relocation!



Weber & Opp (2020): Depth distribution of CMP in a) real floodplain samples and b) expected depth distribution according plastic age and sedimentation rates. c) Density plot of the value distribution for both, real and expected values, by depth.

5. Outlook

Active use
of the new marker will provide information to improve dating and chronology

Advancing microplastics research
will standardise analytical methods and eliminate some pitfalls

Unique fingerprint in analytics
by using additives (e.g. plasticisers) and their composition, not only chronology but also traceability (origin analysis) conceivable

2020/21 Pandemic marker
Face masks and gloves enter the environment in large numbers - Annual marker?
Fadara & Okoffo (2020)

Literature *to read on*

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