Development of a Testing and Evaluation Methodology for Polymeric Substances in Soils

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Introduction

Polymers are ubiquitous substances that can be found in different types of ecosystems. Especially within agricultural management, polymers are indispensable. Due to their physicochemical properties, polymeric substances are increasingly used within seed coatings enhancing specific abiotic properties, e.g. water retention [1,2]. Nevertheless, this group of substances is not regulated making reliable environmental evaluation difficult.

To evaluate the environmental behaviour of **intentionally added polymers** to the agricultural landscape without a specific mode of action, a holistic **hazard assessment approach** combining **fate** and **ecotoxicity** is to be developed. For efficient data gathering, the test system should be applicable as screening tool.

Materials & Methods

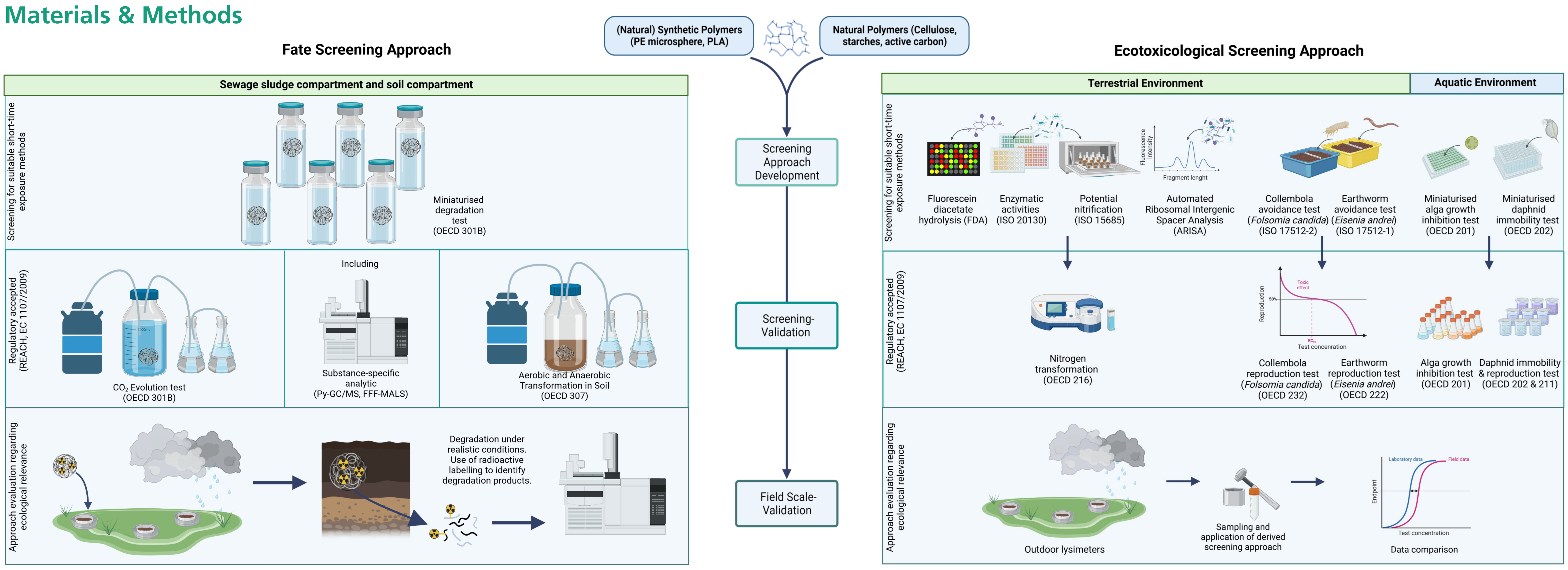

Figure 1: Stepwise approach for developing a hazard assessment approach for polymers.

Fate – Test strategy

- Method selection: fast degradation method for degradation screening
- Incubation in activated sludge medium: high activity of microorganisms
  - REACH, EC 1107/2009 as alignment
  - Measurement of mineralisation and degradation products
  - Method development facilitated by radioactive labelling and transferred to degradation analysis of non-labelled materials
- Polymer testing: as solution/ suspension

Ecotoxicology – Test strategy

- Method selection: short-term exposure methods for effective screening
- Selection of model organisms: comprises exposure route of polymers
  - REACH, EC 1107/2009 as alignment
  - Terrestrial environment: micro-, meso-, macrofauna
  - Aquatic environment: different trophic levels
- Polymer testing: as particle/ filtrate in dependence of physicochemical properties

Fate – Results

First results are available for the recovery of sodium benzoate in 800 and 250 ml incubation vessels. A decrease in the amount of TOC is determined over 14 days. Therefore, a degradation is taking place and the decrease in volume shows little influence on the results. The OECD 301B test of cellulose fibres and carboxymethylcellulose sodium salt determined the mineralisation of the polymers. Even though both substances are based on cellulose a significant difference in their mineralisation in 28 days can be observed.

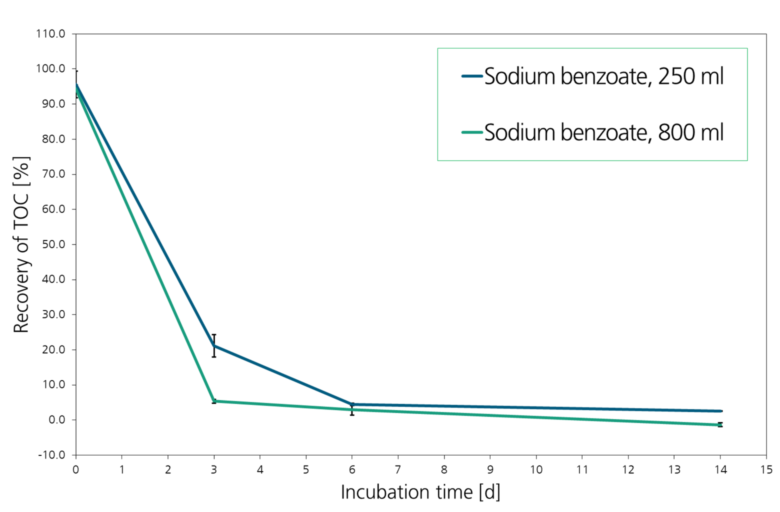

Figure 2: Comparison of the TOC recovery of sodium benzoate in varying sample volumes.

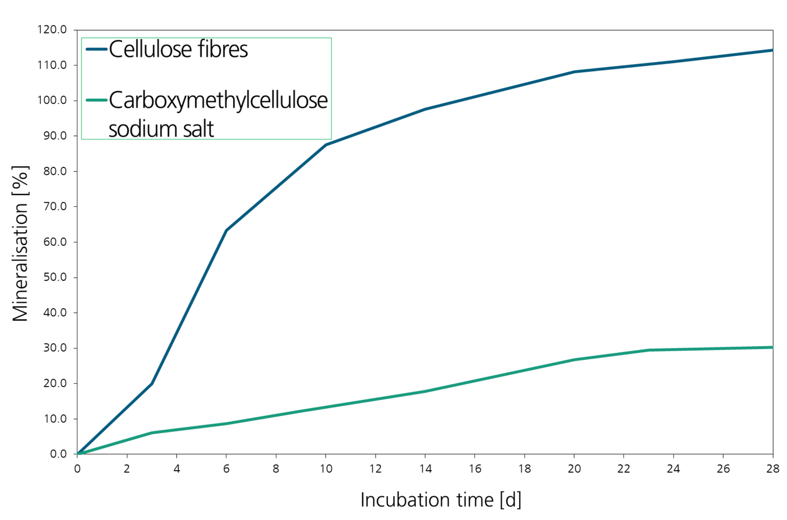

Figure 3: Comparison of the mineralisation of cellulose fibres with carboxymethylcellulose sodium salt.

Ecotoxicology – Results

First results are available for an active char based on coal.

Microfauna: 28 days exposure, RefeSol 01A06 standard soil (70% sand, pH 5.4), test concentrations: 10.0, 100.0, 1000.0 mg/kg dw soil
ISO 15685: dose-response related impact between 4% and 42%
ISO 20130: dose-response related impact on phosphatase, glucosidase and arylsulfatase activity between 25% and 63%

Mesofauna: 28 days exposure, RefeSol 01A06 standard soil (70% sand, pH 5.4), test concentrations: 25.6, 64.0, 160.0, 400.0, 1000.0 mg/kg dw soil
OECD 232: NOEC 400 mg/kg dw soil

Macrofauna: 48 hours to 56 days exposure, RefeSol 01A06 standard soil (70% sand, pH 5.4), test concentrations: 10.0, 100.0, 1000.0 mg/kg dw soil
ISO 17512-1: EC_{10} 15.47, EC_{50} 165.39 mg/kg dw soil
OECD 222: EC_{10} 106.79 mg/kg dw soil (offspring number)

Aquatic: 48 hours exposure, Elendt M4 media, test concentrations: 10.0, 50.0, 100.0 mg/L
Miniaturised OECD 202: no effects of polymers as filtrate and particle on daphnia mobility

Outlook

- Determination of the sensitivity of the screening-approach
- Selection of a suitable set-up by comparing screening test results with validated OECD test results

Outlook

- Proving suitability of FDA for microbiological hazard assessment of soil fungi
- Selection of suitable test methods by comparing screening test results with validation test results

Acknowledgement - The study was funded by Fraunhofer and is part of the PREPARE project SeedPlus.
Figures created with BioRender.

[1] Chang, L., Xu, L., Liu, Y., & Qiu, D. (2021): Superabsorbent polymers used for agricultural water retention. In: Polymer Testing, 94: 107021.
[2] Ostrand, M. S., De Sutter, T. M., Daigh, A. L. M., Limb, R. F., & Steele, D. D. (2020): Superabsorbent polymer characteristics, properties, and applications. In: Agrosystems, Geosciences & Environment, 3(1): 1.