

Ecotoxicity of Biopolymers – Learnings from the Lab to the Field Scale

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Biopolymers are considered sustainable alternatives to synthetic, non-degradable polymers for use in agrotechnical products, such as seed coatings. Therefore, biopolymers remain unregulated, whereas synthetic microparticulate polymers got restricted under EC 2023/2055 [1]. However, ecotoxicity data supporting the exclusion of biopolymers from regulation is missing.

Research questions

In this study, we therefore aimed to answer three main research questions:

- I) Do biopolymers cause ecotoxic effects in aquatic or terrestrial organisms? Can these effects be linked to their substance properties (ionic charge, solubility)?
- II) Which ecotoxicological methods are sensitive for assessing the ecotoxicological concerns regarding biopolymers?
- III) Laboratory vs. outdoor field study: Are laboratory tests suitable to predict the environmental behaviour of polymers at the field scale?

Workflow

To address these questions, various aquatic and terrestrial test methods were selected to investigate ecotoxicity of different biopolymers and modified natural polymers (Figure 1). To validate laboratory tests for field scale predictions, the selected sensitive test methods were applied in a laboratory and outdoor field study. Single substances (alginate – SA, cellulose fibers – JHM) and substance mixtures (cryomilled capsules – 1 & 3CC and seed coatings – 1 & 3CS including alginate, cellulose fibers, activated charcoal – AC) were applied to Refesol 01A test soil, taking into account an environmental realistic scenario.

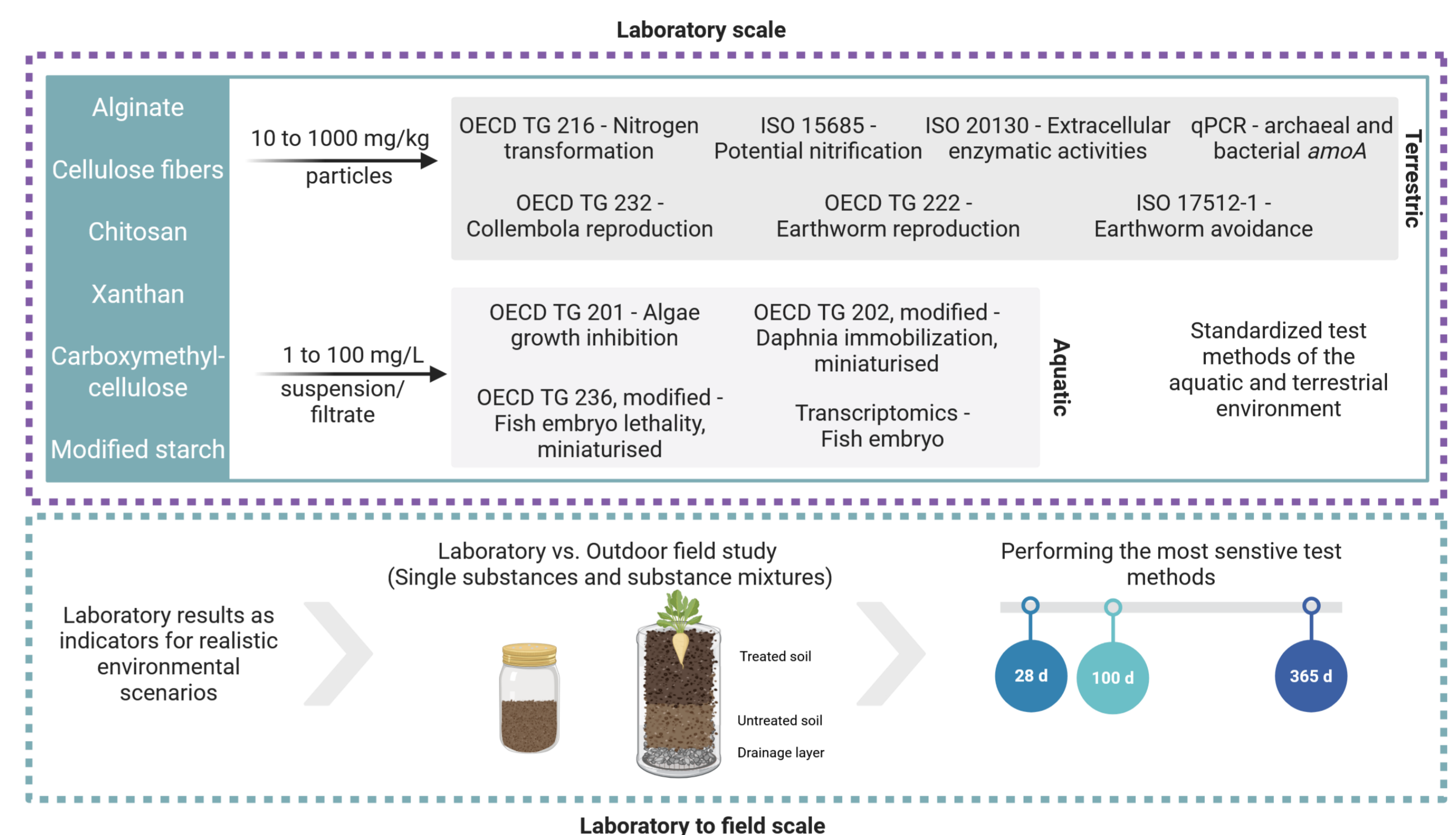


Figure 1: Schematic workflow of the study.

Results and Discussion

I) Ecotoxicity of biopolymers and II) Sensitivity of ecotoxicological methods

The tested substances mainly affected transformation processes linked to **microbial driven soil cycles**, i.e., **ISO 15685 – Potential nitrification and ISO 20130 – Extracellular enzymatic activity**. Here, both inhibitory and stimulatory effects were observed depending on the substance and concentration tested, possibly linked to the **viscosity behaviour** of the polymers [2]. Collembola and earthworm related endpoints were mostly unaffected (LOECs > highest test concentration).

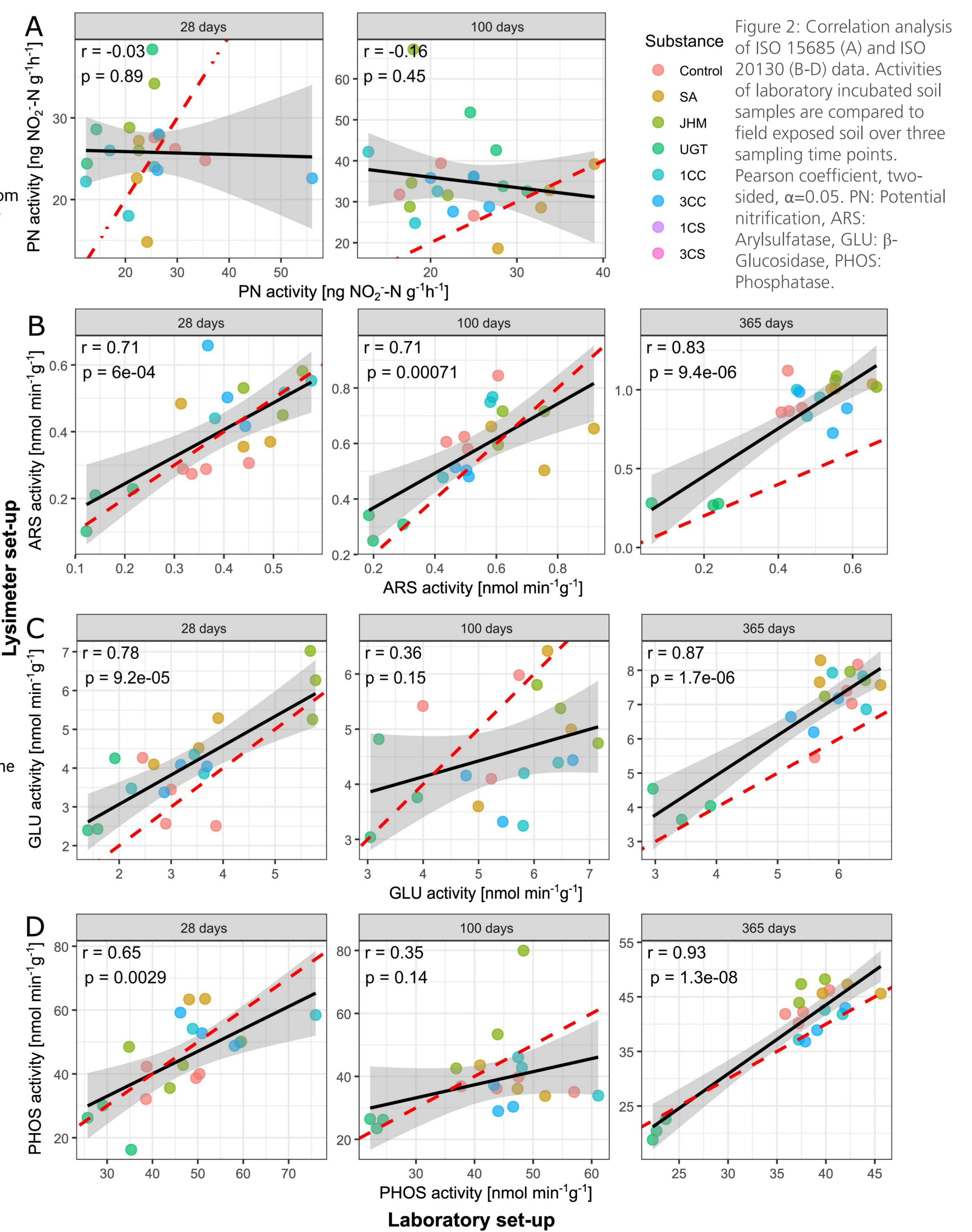
The aquatic dataset of OECD TG 201 suggests that the physicochemical properties and, therefore, the way of substance exposure (filtrate/suspension) affected the ecotoxicological outcome of the tests. As the substances were mostly not soluble, no chemical effects were identified (LOECs > highest test concentration), whereas in the suspensions **physical effects** could be observed. Additionally, indications were given that the **ionic charge** affects the ecotoxicity of the polymer. This is consistent with observations of other studies, as discussed in Winter et al. 2025 [3].

III) Laboratory tests as predictors for polymer behaviour at the field scale

Based on the previous results, ISO 15685 – Potential nitrification and ISO 20130 – Extracellular enzymatic activity tests were selected for the laboratory and outdoor field study. The data analysis indicated a correlation between extracellular enzymatic activity data from laboratory and field-incubated soil samples across all sampling time points (Figure 2). However, potential nitrification showed lower activities in laboratory-incubated soil compared to field-exposed soil over time, resulting in a weak correlation, possibly due to starvation under static laboratory conditions, whereas hydrolase enzymes may be more resilient due to functional redundancy across microbial groups [4].

Conclusions

Overall, the data show that biopolymers can affect the observed ecotoxicological endpoints. Therefore, it should be discussed whether natural polymers should be exempted from regulation without further review. Functional soil microbial tests on the lab scale indicated to be predictive for the field scale and are recommended, supplemented by aquatic tests, for a comprehensive assessment of polymers along the exposure pathway.



[1] EC 2023/2055, 2023. Commission regulation (EU) 2023/2055 of 25 September 2023 amending annex XVII to regulation (EC) no 1907/2006 of the European parliament and of the council concerning the registration, evaluation, authorisation and restriction of chemicals. [2] Winter M., Schlich K. 2025. Natural but threatening? (I) A systematic terrestrial ecotoxicity evaluation of biopolymers and modified natural polymers. Environ. Res., 121665. [3] Winter M., Schlich K. 2025. Natural but threatening? (II) A systematic aquatic ecotoxicity evaluation of biopolymers and modified natural polymers. Environ. Res., 121279. [4] Nicol GW., Prosser JI. 2008. The influence of soil pH on the diversity, abundance and transcriptional activity of ammonia oxidizing archaea and bacteria. Environ Microbiol, 10(11): 2966-2978.