What is the impact of agricultural mulch films on terrestrial ecosystems?

Carmen Wolf[1], Mike Wenzel[1], Matin Funck[1], Björn Fischer[2], Kristin Nehren[2], Ralf Bertling[3], Mona Duhme[3], Dieter Hennecke[4], Karlheinz Weinfurtner[4], Martina Roß-Nickoll[5], Henner Hollert[5,7], Antonia Weltmeyer[5], Kristina Bitter [6], Lars Blank[6], Pauline Ruiz[8], Svenja Dahl[8], Christof Asbach[1], Jochen Tuerk[1]

1) Institut für Energie- und Umwelttechnik e. V. (IUTA), Duisburg, Germany; 2) FISCHER GmbH, Meerbusch, Germany; 3) Fraunhofer UMSICHT, Oberhausen, Germany; 4) Fraunhofer IME, Schmallenberg, Germany; 5) RWTH Aachen University, IUF, Aachen, Germany, 6) RWTH Aachen University, iAMB, Aachen, Germany, 7) Goethe Universität, E3T, Frankfurt. Germany

Introduction

- The worldwide production of plastic increased during the last decades from 1.7 million t in 1950 to 335 million t in 2016 [1].
- Due to their high production volumes, their application and durability, they are becoming increasingly relevant for the environment.
- It is assumed that soils can be a sink for (micro)plastics [2].

- Mulch film is one direct application of plastics on agricultural soils.
- It is used to increase the temperature of the soil for a earlier or later harvest or to decrease the amount of agrochemicals.
- In Europe around 4,270 km² agricultural lands are covered with mulch film [3] with polyethylene (PE) as dominant used material.
- The highest portion of the mulch film will be removed from the field after their use, but the thinner the film the more difficult and time consuming it becomes removing all mulch film from the field after the crop cycle [3].

➔ Fragments of the mulch film can be left on the field and will break down to microplastics

➔ In this project one PE mulch film and two biodegradable (PLA/PBAT) mulch films were tested

Materials and Methods

- As first step the consortium develops a detection methodology, including the sample preparation, that enable the detection of PE microplastics in soils and drainage waters, using Raman spectroscopy, FTIR spectroscopy and TED-GC/MS (Fig 5). With this method different agricultural samples were analysed (Table 1).

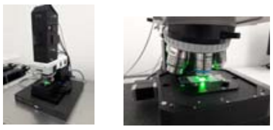
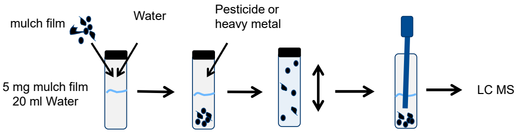


Fig 1: WITec alpha300 R Raman Microscope – FISCHER GmbH

Fig 2: Thermal Extraction / Desorption GC-MS; Gerstel – IUTA e.V.

- The aging of the mulch film was examined in a soil test stand and in a laboratory sewage treatment plant operated with drainage water (Fig. 4).
- The adsorption of heavy metals (Copper) and pesticides (Atrazine, Tebuconazol, Thiacloprid) on fragments of the mulch film were investigated (Fig. 6).



- A Life Cycle Assessment (Cradle-to-Grave) was carried out. For this purpose, 30 µm PE and 10 µm PLA/PBAT mulch films were compared with a Functional Unit of 1 ha mulch film used for zucchini cultivation (Fig 7).
- To determine the transport behaviour and fate of the plastic fragments in natural soils, ^{14}C marked polymers were tested in outdoor lysimeter experiments (Plattform 7254).

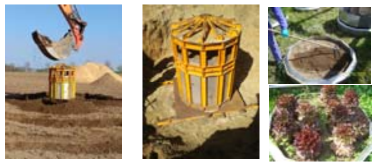


Fig. 3: Preparation of the Lysimeter experiments – Fraunhofer IME

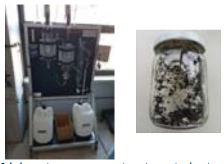


Fig 4 laboratory sewage treatment plant – Fraunhofer UMSICHT

- Experiments examining ecotoxicological effects of the mulch fragments on springtails and earthworms were conducted and endocrine activity, genotoxic potential, dioxin-like potency of mulch film eluates were studied. Furthermore, the troyan horse effect of mulch films fragments and pesticides was investigated (Poster 8549).
- Additionally, the "upcycling" of mulch films by bacteria was examined. Plastic fragments are degraded in the laboratory by microorganisms and converted into new plastic molecules. Such molecules will then be returned to the value chain and thus increase the recyclable fraction.

Results

Sample preparation

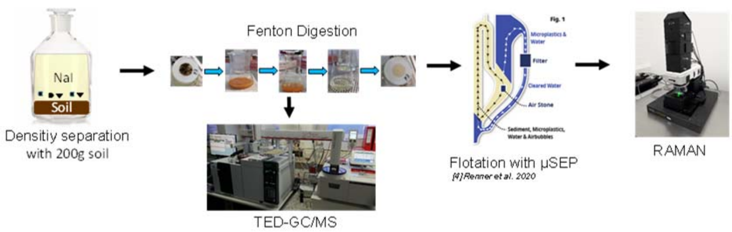


Fig 5: Sample preparation of the soil samples for TED-GC/MS and RAMAN spectrocopy analysis. The soil samples were taken in the fields in a diagonal with a Pürkhauer sampler.

TED-GC/MS Results

Tab. 1: TED-GC/MS results of different field sample. LOQ PE: 8.4 µg absolute, LOQ PS: 0.3 µg absolute.

	µg PE / g Soil	µg PS / g Soil	µg PLA/PBAT / g Soil
Field with Biodegradable film_A	0.2	LOQ	0.1
Field with Biodegradable film _A2	4.4	LOQ	0.3
Field with Biodegradable film_B	5.2	LOQ	0.5
Field without film_A	0.8	LOQ	0.1
Field without film_A2	1.4	0.9	0.3
Field without film_B	LOQ	LOQ	0.5
Field with mulchfilm / strawbeeries_A	LOQ	LOQ	0.1
Field with mulchfilm / strawbeeries _B	0.5	LOQ	2.2
Field close to motorway service station_A	LOQ	LOQ	0.1
Field with Asparagus film_A	LOQ	LOQ	0.2
Field with Asparagus film_B	0.8	LOQ	0.4
Reference soil RefesolA01	8.2	LOQ	0.4
A = sampling March 2021, B = Sampling June 2021, A2 = sampling shiped with plastic bag			

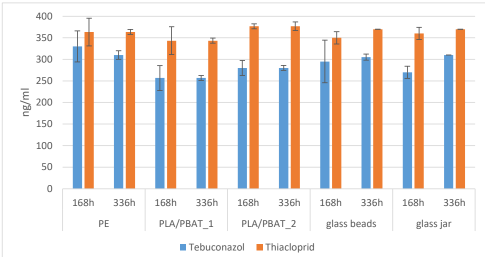


Fig. 6: Tebuconazol and Thiacloprid in the supernatant after different time durations of shaking, with PE mulch film (blue), bio mulch film (PBAT and PLA) (green) and a second bio mulch film (PBAT and PLA) (red).

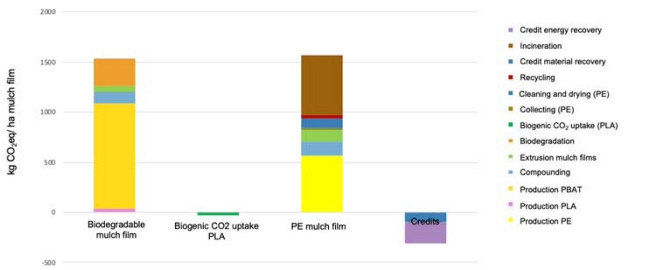


Fig 7: Results of the LCA Cradle-to-Grave analysis - Global Warming Potential (GWP) in kg CO2-eq/ha mulch film. In this analysis, PE films are collected, 80 % are incinerated and 20 % recycled. PLA/PBAT mulch films biodegrade on the field

Conclusion

- Method for the detection of microplastic in soils was established.
- No correlation between the type of agriculture and the concentration of microplastics in the studied soils.
- In drainage water, degradation of the mulch film began after 8 weeks. Increase in density by up to 70%. Change of the IR spectra due to the aging was observed.
- No significant adsorption of Copper, Tebuconazol and Thiacloprid was observed.
- LCA: similar GWP profile for both mulch films.
- Effect studies: Endocrine effects detected, Aged films show reduced effects, no effects on soil organisms observed, no significant differences between PLA/PBAT & PE film.
- Upcycling: Bacterial strain for upcycling the films identified and cultivated.

[1] PlasticEurope. 2017. Plastic-the facts 2017. Bruessels.PlasticEurope
[2] Duis K, Coors A. 2016. DOI: 10.1186/s12302-015-0069-y [3] Steinmetz et al. 2016. doi:10.1016/j.scitotenv.2016.01.153
[4] Renner et al. 2020. doi: 10.1016/j.mex.2019.11.006

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