



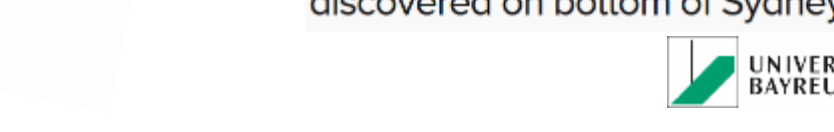
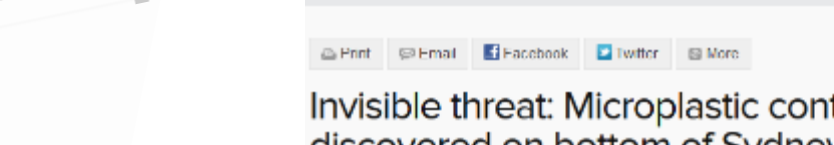
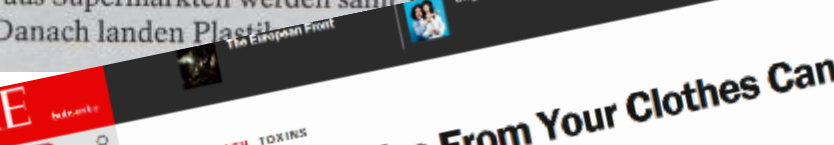
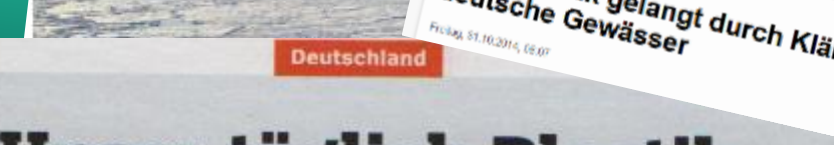
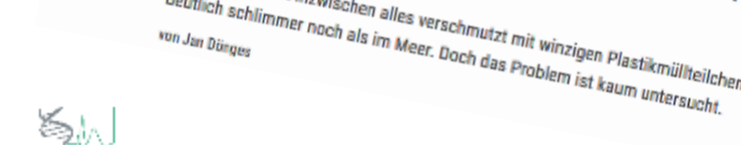
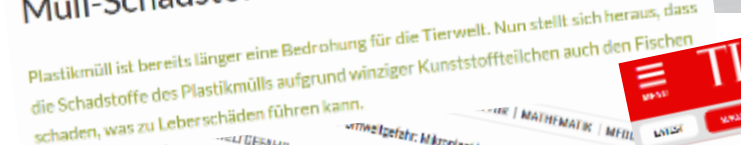
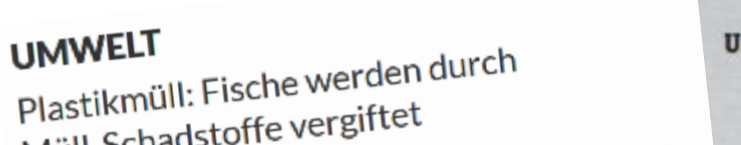
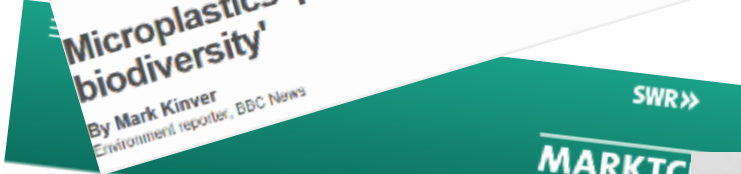
Biodegradable Plastic: Solution or Threat?

Prof. Dr. Ruth Freitag

Bioprocess Engineering

University of Bayreuth

Plastic, a great material, but a problem



Invisible threat: Microplastic contamination discovered on bottom of Sydney Harbour

Commodity Plastics

RRR: Replace, Reuse, Recycle



Biodegradable Plastics: Solution or threat?



Biodegradability:

The material breaks down into CO₂, H₂O and biomass within a reasonable amount of time.

Certification according to DIN EN 13432

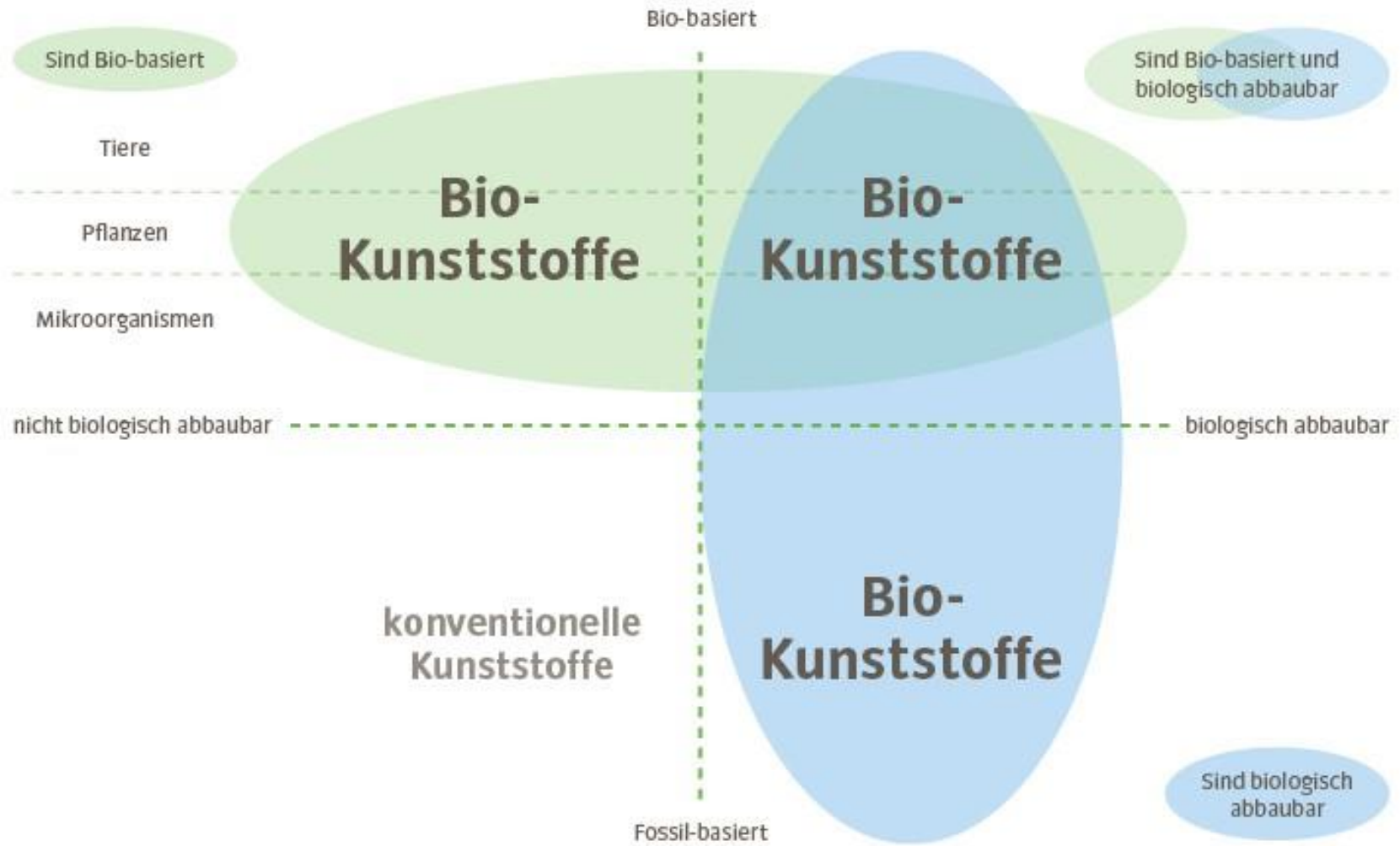


Biodegradability: Within 6 months 90 % of the material is gone

Compostability: After 12 weeks, the material has to be degraded into particles < 2 mm.

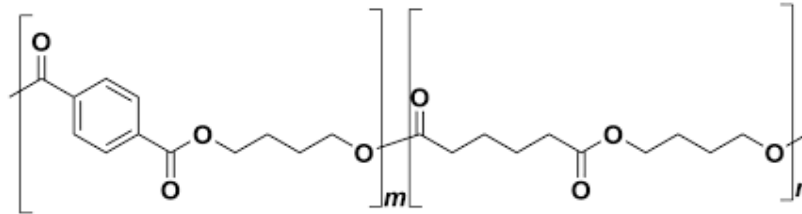
(Test under standardized laboratory conditions)

Biodegradable Plastics: Solution or threat?



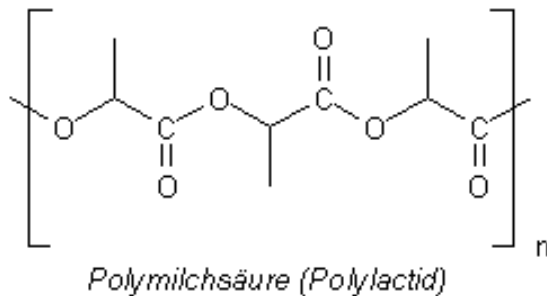
Biodegradable Plastics: Solution or threat?

PBAT: polybutylene adipate terephthalate



But, does it at least do its job?

PLA: Polylactid acid, polylactide





CRC (collaborative research center) 1357

„MIKROPLASTIK“

Understanding mechanisms and processes of biological interaction, environmental transport, and formation

Biowaste treatment

- **Collection in Germany:**
64 kg/Person and year¹
- **Biowaste contains between 1 und 5 wt% plastic²**

→ Each year 53'000 to 266'000 tons of plastic enter the biowaste treatment plants

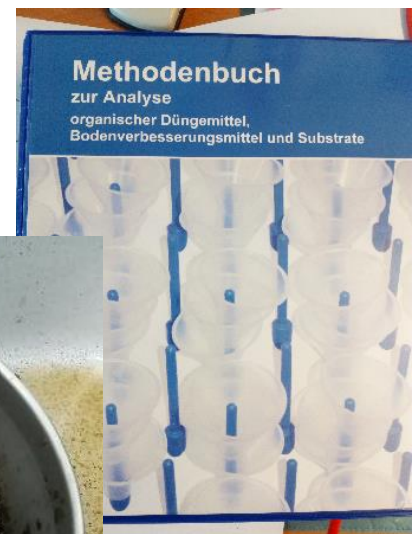
1: Statistisches Bundesamt:

<https://de.statista.com/statistik/daten/studie/957294/umfrage/bio-und-gruenabfall-prokopf-aufkommen-in-deutschland/>

2: Erkenntnisse aus dem Projekt Babba; Zusammenarbeit mit BEM Umweltservice GmbH, gefördert vom Ministerium für Umwelt, Klima und Energiewirtschaft Baden-Württemberg

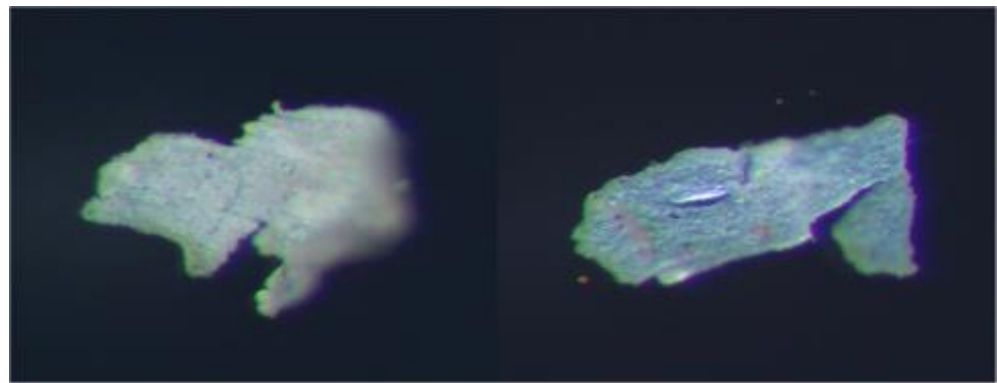


- Drying to constant weight (105°C)
- Sieving (“Quadratloch”, 5 mm, **1 mm**)
- Picking with tweezers, magnet
- Weighing → < 0.1 wt%



Contaminants

- Glass
- Metal
- **Plastics**
- Paper
- Others



Links: Pflanzenmaterial, rechts: Polyesterpartikel (40fache Vergrößerung)

Quelle: Bachelorarbeit, J. Möller

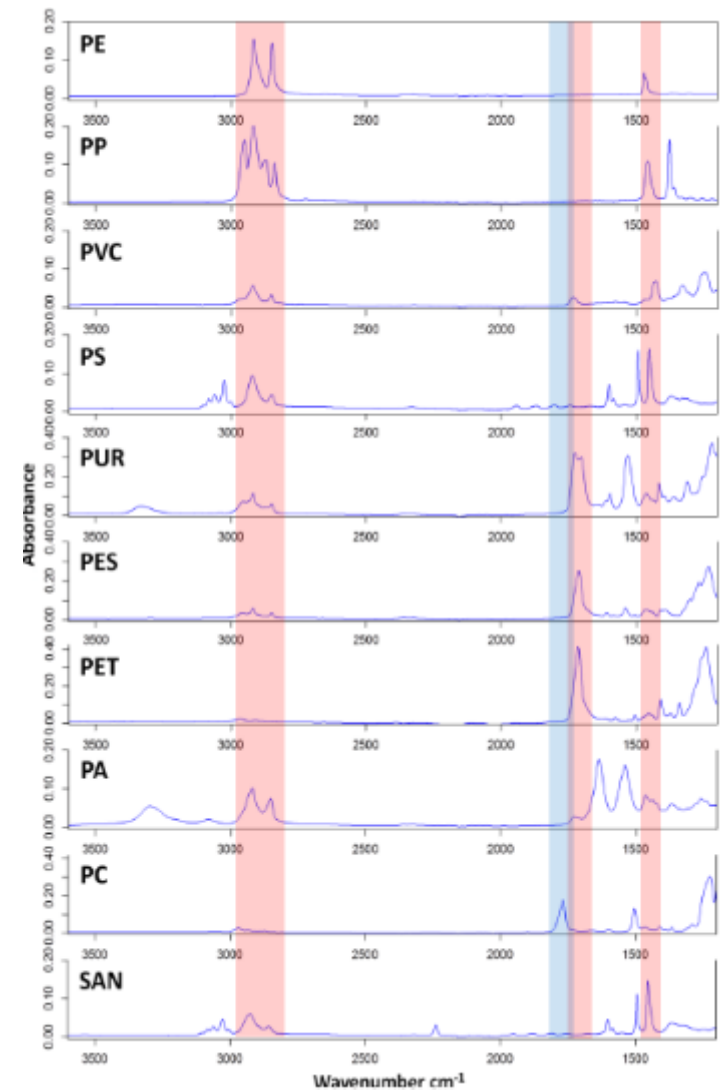
ENVIRONMENTAL STUDIES

Organic fertilizer as a vehicle for the entry of microplastic into the environment

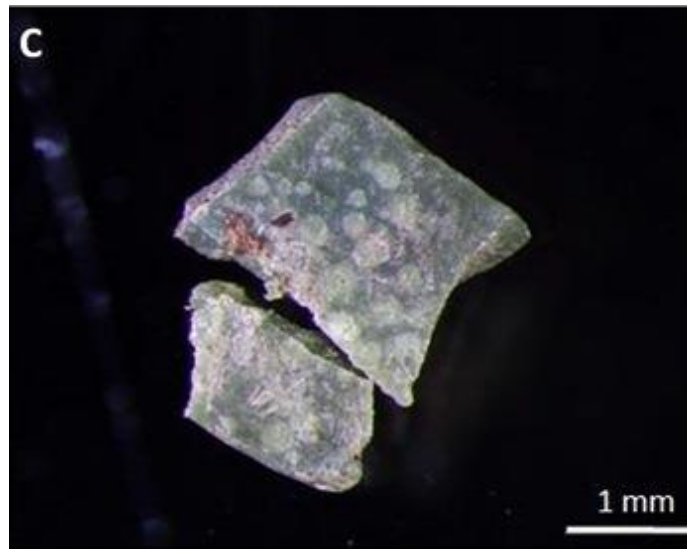
Nicolas Weithmann,¹ Julia N. Möller,² Martin G. J. Löder,² Sarah Piehl,²
Christian Laforsch,^{2*} Ruth Freitag¹



Figure 8: Sieve retention of a small amount of compost A. From left to right: >5mm, 2-5mm, 1-2mm (author's



Mikrokunststoffe in Komposten und Gärprodukten aus Bioabfallverwertungsanlagen und deren Eintrag in Böden Erfassen, Bewerten, Vermeiden



Investigated plants



Composting plant

Agricultural
Biogas plant

Digester-Composter



Liquid and solid fertilizer
(Compost, liquid and solid
digestate)

MiKoBo - Findings

Waste and Biomass Valorization (2023) 14:873–887

<https://doi.org/10.1007/s12649-022-01870-2>

ORIGINAL PAPER



Microplastic Contamination of Composts and Liquid Fertilizers from Municipal Biowaste Treatment Plants: Effects of the Operating Conditions

Thomas Steiner¹ · Julia N. Möller² · Martin G. J. Löder² · Frank Hilbrig¹ · Christian Laforsch² · Ruth Freitag¹ 

Received: 16 February 2022 / Accepted: 1 July 2022 / Published online: 17 August 2022

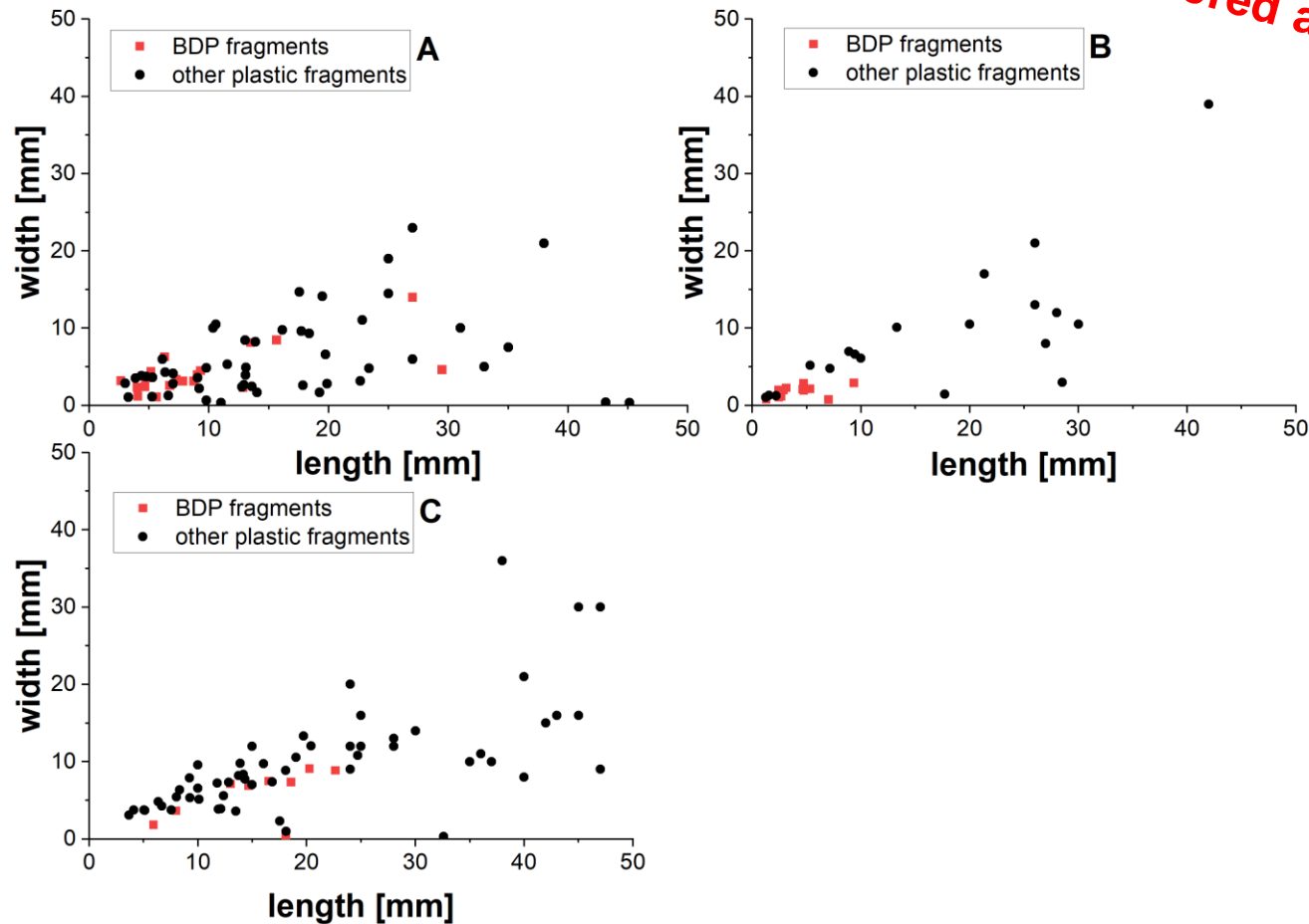
© The Author(s) 2022

- Sieving is efficient for the removal of particles > 5 mm
- Hardly any contamination of agricultural biogas plants or most composts
- **BDP in composts from biowaste digesters/composters**
- Up to 10'000 plastic particles (20 – 1000 µm) are found per Liter (!) of the liquid digestate, with roughly 50 % with BDP (biodegradable polymer) signatures

Partikel/kg DW Compost	Plant 1	Plant 2	Plant 3		Plant 4		Plant 5
	FC	FC	PDC	FC	PDC	FC	FC
> 5 mm (Sieving fraction)	84	29	223	53	60	15	98
BDP-Fragments > 5 mm	20 %	----	13 %	----	7 %	----	----
1- 5 mm (Sieving fraction)	42	24	50	51	8	6	16
BPD-Fragments 1 - 5 mm	43 %	80 %	6 %	4 %	----	----	----

Particle size distribution

BDP no longer considered a contamination



BDP fragments mainly in the range < 5 mm



BabbA

Biologisch abbaubare Beutel
in der Bioabfallverwertung



Baden-Württemberg

MINISTERIUM FÜR UMWELT, KLIMA UND ENERGIEWIRTSCHAFT

What about the other composts?

Extraction of PBAT and PLA out of 50 – 100 g compost with chloroform*
→ Quantification with ^1H -NMR

Assuming a thickness of 23 μm for compostable foils*
this results in an area of 17 to 150 m^2 **per ton compost dry weight**.

* Density: PLA: 1240 kg/m^3 ; PBAT: 1260 kg/m^3

**If we assume that 1 ton of dry compost is applied to 1000 m^2 arable soil:
→ 15% of the fertilized area is covered in “biodegradable” plastic.**

	Plant A	Plant B	Plant C		Plant D	
	FC	FC	PDC	FC	PDC	FC
C_{PLA} [ppm]	827	1199	690	250	1972	898
C_{PBAT} [ppm]	686	3130	581	258	274	75
wt% in compost	0,15	0,43	0,13	0,05	0,22	0,10

**Biowaste entering the plant was NOT investigated!
Hence the degree of degradation is not known.**

* Method adapted from: Nelson, Taylor F., et al. "Quantification of synthetic polyesters from biodegradable mulch films in soils." *Environmental Science & Technology* 54.1 (2019): 266-275.

Th. Steiner, L.-C. Leitner, Y. Zhang, J.N. Möller, M.G.J. Löder, A. Greiner, Ch. Laforsch, R. Freitag (2024) **Detection and Specific Chemical Identification of Submillimeter Plastic Fragments in Complex Matrices such as Compost**, Sci. Rep., 14:2282, doi.org/10.1038/s41598-024-51185-6

	Composts from Greenery & Cuttings							
Plant number	#1	#2	#3	#4	#5	#6	#7	#8
PBAT	5123	1570	2884	0	0	0	0	2079
PP	603	1570	384	649	703	3460	1110	331
PE	301	897	1153	162	0	546	888	378
PS	0	0	0	324	0	0	444	898
PET	0	224	0	0	234	0	0	47
PVC	0	0	192	0	234	0	0	47
Other particles	0	448	384	0	468	364	0	0
Sum	6027	4709	4998	1135	1640	4371	2442	3780

PBAT is found only in biowaste composts. The material ends to dominate the < 1mm fraction even in composts that gave no evidence of PBAT fragments > 1mm

Microplastic fragments/ particles size 10 – 1000 µm found per kg of dry compost. Plants #1 to #3 produce compost from biowaste, plants #4 to #7 from greenery and cuttings, plant #8 is a two-stage system for biowaste treatment first by anaerobic digestion followed second by composting of the solid digestate.

n = 9 for simple biowaste composts, n = 12 for composts from greenery & cuttings.

Recovered (larger) fragments had a higher crystallinity than typical bags

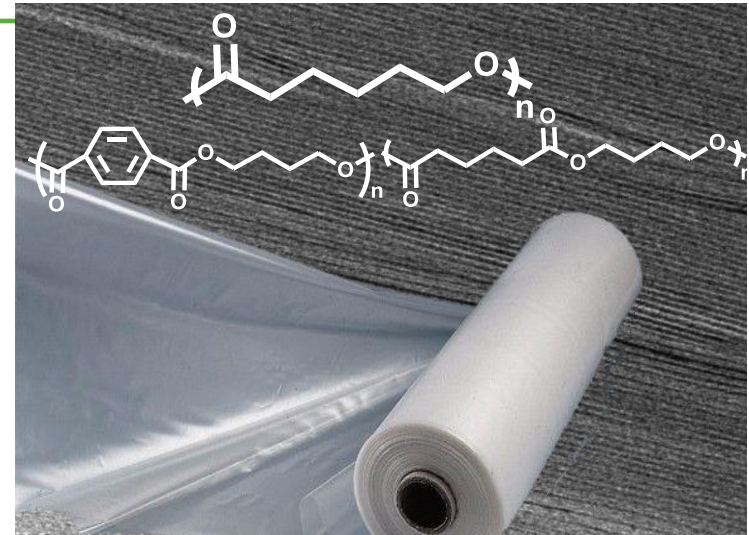
Th. Steiner, Y-H. Zhang, J.N. Möller, S. Agarwal, M.G.J- Löder, A. Greiner, Ch. Laforsch, R. Freitag (2022) **Municipal biowaste treatment plants contribute to the contamination of the environment with residues of biodegradable plastics with putative higher persistence potential**. Science Reports. 12(1), DOI:10.1038/s41598-022-12912-z

Biological degradation in the environment ????

Biodegradable Polymeric Materials—Not the Origin but the Chemical Structure Determines Biodegradability

Uwe Witt,* Motonori Yamamoto, Ursula Seeliger,
Rolf-Joachim Müller, and Volker Warzelhan*

*Dedicated to Professor Hans-Jürgen Quadbeck-Seeger
on the occasion of his 60th birthday*



FULL PAPER

Water

Global
Challenges

www.global-challenges.com

Fate of So-Called Biodegradable Polymers in Seawater and Freshwater

Amir Reza Bagheri, Christian Laforsch, Andreas Greiner,* and Seema Agarwal*

Only **amorphous** PLGA is
100% biodegradable

~~Poly(L-lactide)
Polyhydroxybutyrate
Polycaprolactone
Ecoflex~~

Semicrystalline so-called
“biodegradable” polymers are
not environmentally
degradable

What happens in the Environment?

Nobody knows, but

Conclusion

Biodegradable in principle a great idea, but current materials are underwhelming.

Alternatives ?

Degradation of standard commodity plastics??

The estimated half life of cellulose (e.g. Papier)
under abiotic conditions at 25 °C in water is ca.
5 to 8 million years.

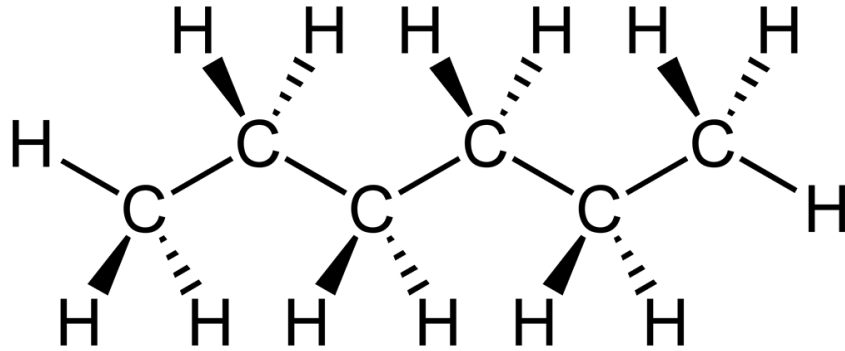
In the presence of suitable biocatalysts
(microorganisms) cellulose is degraded within a few
hours

The reaction is accelerated more than
10 000 000 000-fold.

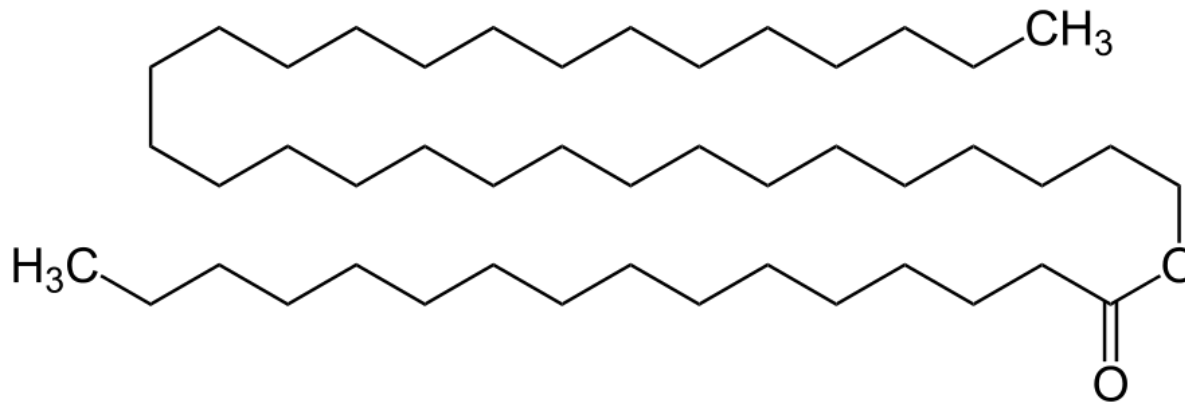


Degradation of standard commodity plastics??

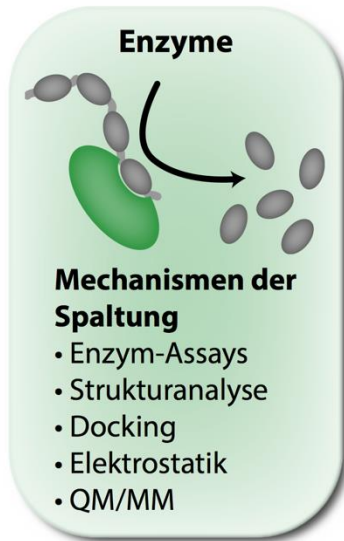
Structure: Polyethylene, Polypropylene,



Beeswax



Enzymatic degradation of plastic (PET, Höcker group, UBT)

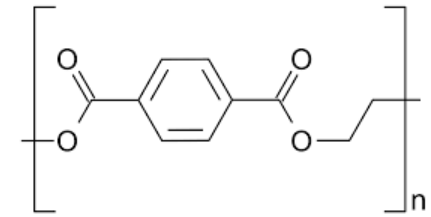


PET – not biodegradable

2016 – PET-degrading organism found

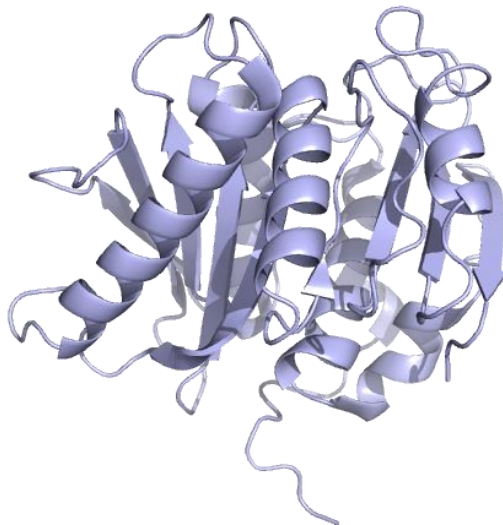


Ideonella sakaiensis
(Yoshida *et al* Science 2016)



Polyethylenterephthalat

PETase as new model enzyme



Polystyrene & Polyethylene is digested by beetle larvae or its intestinal microbiome respectively.



Thank you for your attention !

