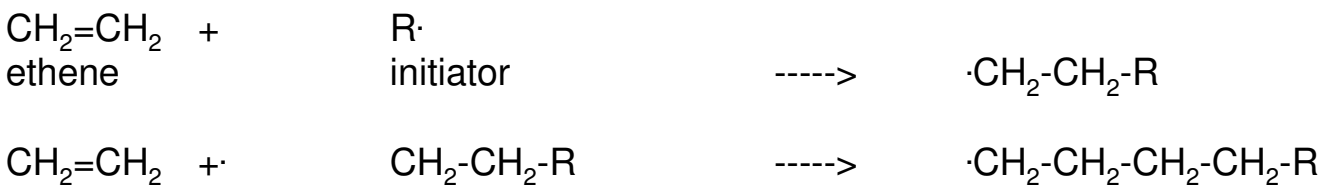
Degradation of Plastic Bags (?)

Barbara Alfer

Polyethylene, PE

- obtained by polymerizing ethylene gas



Process continues to form polyethylene $[\text{-}CH_2\text{-}CH_2\text{-}]_n$

- classified into several different categories - based mostly on density and branching

  e.g. LDPE (low density; 0.91-0.94 g/cm^3), HDPE (high density; 0.95-0.97 g/cm^3)

- over 60 million tons are produced worldwide every year

Why is PE so popular?

- **versatile applications**
- **easy to produce**
- **inexpensive**
- **light weight**
- **resitant**

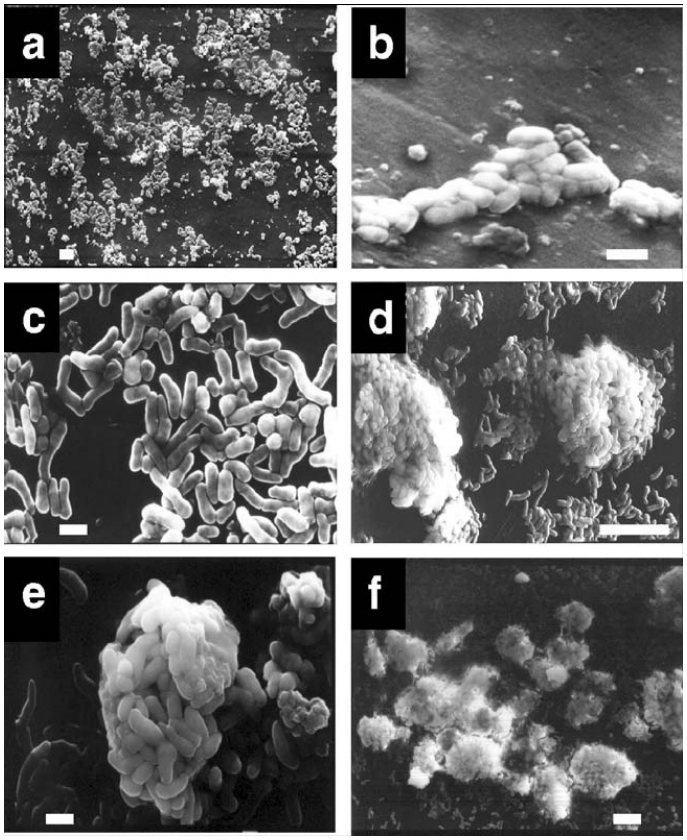
Facts about plastic bags:

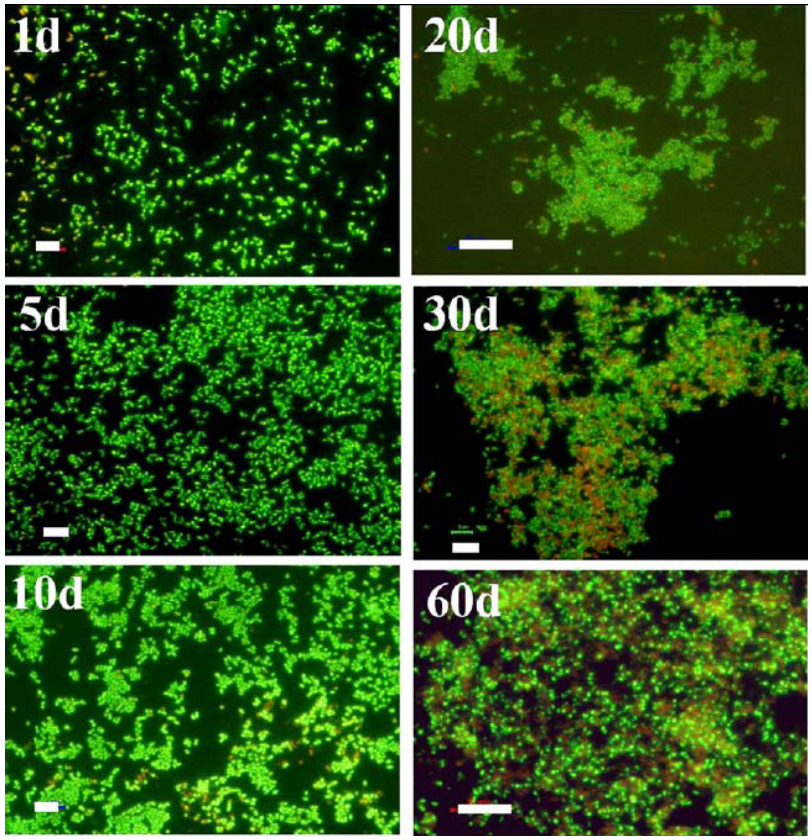
- **500,000,000,000 (that's 500 billion)**
  annually, or almost **1 million per minute**
- less than 1 % recycled
- used for only 20 minutes
  persist for up to 1,000 years
- detected north of the Arctic Circle,
  as far south as the Falkland Islands
  & even in the orbit (!)

- cause over a million seabirds, 100,000 sea turtles and 100,000 marine mammals deaths every year
- in South Africa they have been dubbed the "national flower"
  - so many can be seen flapping from fences and caught in bushes

reusablebags.com; poconorecord.com; timesonline.co.uk; spiegel.de

Polyethylene-degrading bacterium *Rhodococcus ruber* (C208)





- C208 adheres to PE immediately upon exposure
- high viability even after 60 days
- initial biofilm differentiates (stepwise process lasts ~20h) into cell-aggregation-forming microcolonies

Sivan, A., Szanto M., Pavlov V. (2006)

Polyethylene-degrading bacterium *Rhodococcus ruber* (C208)

More results & Conclusion:

- high preference for the biofilm mode of growth (60:1 biofilm/planktonic cells)
- PE lost ~7.5 % of its initial weight in 8 weeks (linear pattern: 0.86% per week, r^2=0.98)

High biofilm survival rate (up to 60 days) & PE sole carbon and energy source

⟶ confirms efficiency of C208 in utilizing polyethylene

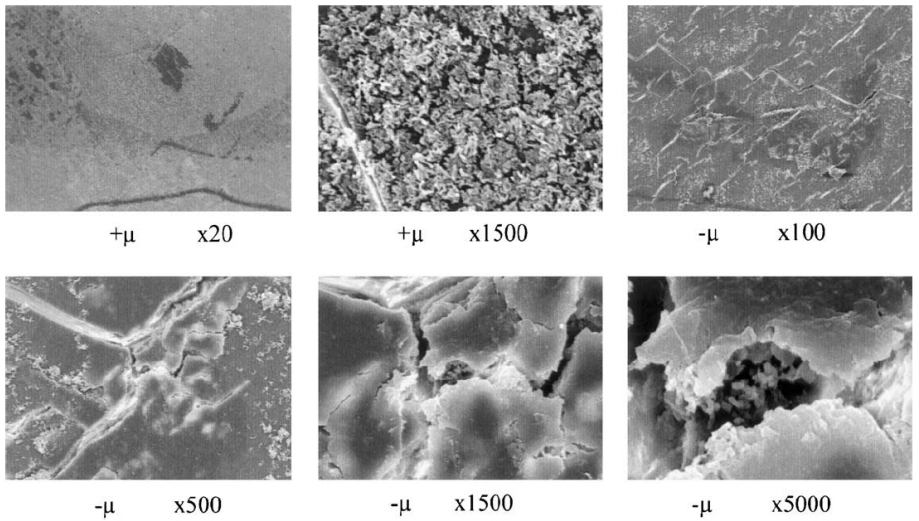
Hypothesis: Enzymatic oxidation by laccase (copper binding enzyme; phenol oxidase) plays a major role in biodegradation of polyethylene

1. Addition of copper affected induction & activity of laccase (13x increase of its mRNA) and enhanced biodegradation of PE by 75 %
2. PE incubated with extracellular laccase showed reduction of 20 % in the average Mw

Sivan, A., Szanto M., Pavlov V. (2006)

Biodegradable Polymers, BPs

- Totally Degradable Plastic Additves (TDPA™): added in small quantities to common plastics as e.g. PE
  ⟶ oxo-biodegradation



- BPs from starch and cellulose

- BPs from Polyesters:
  Polyhydroxylalkanoates, PHAs (widespread synthesis by microbes; corresponding abundance of microbes producing PHA-degrading enzymes)
  Poly(lactic acid), PLA (degrades primarily by hydrolysis)
  Poly(ε-caprolactone), PCL

BUT: still **more expensive** than common plastics *and*
no infrastructure of bioactive systems for the disposal of non-water-soluble BPs

Bonhomme S. et al. (2003); Gross R. A., Kalra B. (2002)

http://www.eza.cc/Pressearchiv.htm

Thank you

for

listening!

DPA

Literature and links:

Bonhomme S. et al. (2003): Environmental biodegradation of polyethylene. *Polymer Degradation and Stability 81: 441-452*

Gross R. A., Kalra B. (2002): Biodegradable Polymers for the Environment. *Science 297: 803-807*

Sivan A., Szanto M., Pavlov V. (2006): Biofilm development of the polyethylene-degrading bacterium *Rhodococcus ruber*. *Applied Microbiology and Biotechnology 72: 346-352*

http://www.asm.org/ASM/files/ccLibraryFiles/Filename/000000002940/Program%20Abstract%20Book.pdf

Poster Abstracts A43, Sivan A. et al.

http://profiler.bgu.ac.il/frontoffice/ShowUser.aspx?id=698

http://www.reusablebags.com/facts.php?id=4

http://www.spiegel.de/wirtschaft/0,1518,510161,00.html

http://www.timesonline.co.uk/tol/news/environment/article3463543.ece

http://www.poconorecord.com/apps/pbcs.dll/article?AID=/20080506/MULTIMEDIA02/80505016