Assessing the Fate of Plastics: Colonization and density changes

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Colonization

Microbial biofilms influence density, sinking and consumption of PMD?

Degradation/Fragmentation

Consumption of microplastics by microbial food web and higher trophic levels?

Inoculation of PMD with potential pathogens?

Transfer of pathogens and HABs to multiple trophic levels including filter feeders via microplastics?

Biodegradation

C-substrate + 6O₂ → 6CO₂ + 6H₂O
Plastic reaches the sea floor
20x40cm pieces of LDPE

HOLMSTRÖM “Plastic films on the bottom of the Skagerack”
“Fouling of plastic materials was generally preceded by the formation of a transparent slimy biofilm on the surface.”
Plastics on the Sargasso Sea Surface

Abstract. Plastic particles, in concentrations averaging 3500 pieces and 290 grams per square kilometer, are widespread in the western Sargasso Sea. Pieces are brittle, apparently due to the weathering of the plasticizers, and many are in a pellet shape about 0.25 to 0.5 centimeters in diameter. The particles are surfaces for the attachment of diatoms and hydroids. Increasing production of plastics, combined with present waste-disposal practices, will undoubtedly lead to increases in the concentration of these particles. Plastics could be a source of some of the polychlorinated biphenyls recently observed in oceanic organisms.

While sampling the pelagic Sargasso community in the western Sargasso Sea, we encountered plastic particles in our neuston (surface) nets. The occurrence of these particles on the sea surface has not yet been noted in the literature [we also collected petroleum lumps, which have received attention (1, 2)].

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"At present, the only known biological effect of these particles is that they act as a surface for the growth of hydroids, diatoms, and probably bacteria."
A diverse microbial “reef”

PHOTOTROPHS

PREDATORS

Symbionts?

Heterotrophs

All scale bars = 10µm

Zettler, Mincer, Amaral-Zettler 2013
Colonization Experiments
**Bacterial Succession on PE SEM vs. (rRNA amplicon marker gene)**

Diatoms (chloroplasts)

Saprospiraceae

Rhodobacteraceae

Cyanobacteria
Exp 1: Diatoms, Pellets, and density gradient

PE
PP
PS
PHA
PLA

+ Diatom culture isolated from plastic

PP and HDPE

1.02 g cm\(^{-3}\) standard (SW is 1.029)

PS

1.13 g cm\(^{-3}\) standard

PHA and PLA

1.12 g cm\(^{-3}\) diatoms

0.90 0.95

1.04

1.20 1.25

Light

Heavy
Exp 2: Sheets and films have far higher SA:Vol ratios, determined mainly by thickness.
Exp 3: Defined polymers, 6 thicknesses, 5 microbes

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<th>Thickness in mm</th>
<th>0.0254</th>
<th>0.0508</th>
<th>0.0762</th>
<th>0.1016</th>
<th>0.1524</th>
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<td>HDPE</td>
<td>0.962 g/cm³</td>
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<td>LDPE</td>
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<td>LLDPE</td>
<td>0.918 g/cm³</td>
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</table>

5 cultures:
2 diatoms
2 cyanobacteria
1 dinoflagellate
Plus a control
Microbes alone CAN cause sinking, but only with dense growth on pieces with high SA:Vol ratios

Prorocentrum lima

Phormidium sp.
Impact of whole colonizing community in natural settings?
HDPE
0.1mm thick

2 weeks 4 weeks 6 weeks
y = 341.67x - 331.42
$R^2 = 0.9842$

Density calibration 2019-10-08

HDPE 0.051mm seawater

mm from surface

Density
Comparison of average density 3 polymers

Polymer density over time

- HDPE
- LDPE
- LLDPE

Depth in density gradient

Weeks

- May
- October

1.13 g/cm³
Fragmentation leads to an increase in SA:Vol, but also influences who can colonize.
So, there is more to sinking than just SA:vol...
“Fragmentation” leads to range of densities
Large pieces support larger, dispersed colonizers
WE OFFER 3 KINDS OF SERVICES

GOOD-CHEAP-FAST

BUT YOU CAN PICK ONLY TWO

GOOD & CHEAP WON'T BE FAST

FAST & GOOD WON'T BE CHEAP

CHEAP & FAST WON'T BE GOOD

Provide at least ranges of densities that will be helpful to modelers
In progress:

• Quantify the influence of fragment size on density
• Calibrate live vs. fixed density, allowing us to compare different areas, seasons using archived samples
• Sequencing, including eukaryotes to move beyond descriptive list of groups, and to examine relationships between microbes and metazoans
Conclusions

• Microbial populations colonize plastic marine debris quickly

• Microbes alone can in some cases cause sinking of plastics with high SA:Vol ratios

• The biofilm can also influence sinking due to:
  • Colonization by invertebrates
  • Ingestion of plastic and incorporation into fecal pellets

• Fragmentation results in higher SA:Vol ratios, but due to uneven colonization by larger/denser organisms, this does not always result in increases in density

• Changes in microbial and metazoan colonization regionally and seasonally may result in periodic pulses of plastic from the surface into the sediments
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