ARE MICROPLASTICS A NEW THREAT FOR THE PLANKTON FOOD WEB?

In situ and experimental considerations

Dorothée VINCENT
INTRODUCTION

- WHAT are microplastics?
- WHERE do they come from?
- WHY do MP matter?
- WHO is impacted?
INTRODUCTION

WHAT are microplastics?

MARINE LITTER …‘any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment’

Galgani et al. 2010

Browne et al. (2015)
INTRODUCTION

WHAT are microplastics?

MARINE LITTER …’any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment’
Galgani et al. 2010

MICROPLASTICS are MARINE LITTER < 5 mm in diameter

Browne et al. (2015)
INTRODUCTION

WHAT are microplastics?

a) 140 μm diameter polyamide yellow-orange bead,
b) 790 μm diameter grey-green polyethylene fragment, and
c) a 160 μm long blue PVC fibre.

Cole et al. 2014

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Acronym</th>
<th>Full name and uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PET</td>
<td>Polyethylene terephthalate - Fizzy drink bottles and frozen ready meal packages.</td>
</tr>
<tr>
<td>2</td>
<td>HDPE</td>
<td>High-density polyethylene - Milk and washing-up liquid bottles</td>
</tr>
<tr>
<td>3</td>
<td>PVC</td>
<td>Polyvinyl chloride - Food trays, cling film, bottles for squash, mineral water and shampoo.</td>
</tr>
<tr>
<td>4</td>
<td>LDPE</td>
<td>Low density polyethylene - Carrier bags and bin liners.</td>
</tr>
<tr>
<td>5</td>
<td>PP</td>
<td>Polypropylene - Margarine tubs, microwave-able meal trays.</td>
</tr>
<tr>
<td>6</td>
<td>PS</td>
<td>Polystyrene - Yoghurt pots, foam meat or fish trays, hamburger boxes and egg cartons, vending cups, plastic cutlery, protective packaging for electronic goods and toys.</td>
</tr>
<tr>
<td>7</td>
<td>Other</td>
<td>Any other plastics that do not fall into any of the above categories. For example melamine, often used in plastic plates and cups.</td>
</tr>
</tbody>
</table>
**INTRODUCTION**

- **WHERE do they come from?**
  - Industrial activities
  - Personal Care / Cleaning house
  - Recreational activities
  - Macroplastics fragmentation
    - UV radiations
    - Waves
    - Physical/biological abrasion

Andrady (2011)
INTRODUCTION

WHEN did MP start to matter?

- Microplastics = « Emerging pollutants »
INTRODUCTION

WHEN did MP start to matter?

- Microplastics = "Emergent pollutants"
- Back to the 1970s (Carpenter & Smith 1972)
- "Ocean garbage patches" (Moore et al. 2001)
- "Microplastics" (Thompson et al. 2004)

1960 : 0.5 million tons yr⁻¹
2013 : 300 millions tons yr⁻¹

Avio et al. 2016
INTRODUCTION

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Avio et al. 2016
INTRODUCTION

WHY do MP matter?

Lin (2016)
INTRODUCTION

 WHY do MP matter?

• MP are everywhere
  - from Surface to Bottom
  - from pole to pole
  - marine biota

Ivar Do Sul & Costa (2014)
INTRODUCTION

WHY do MP matter?

- MP are everywhere

- MP are within the size range available prey
  - Effective ingestion by Invertebrates and Vertebrates
    Polychaetes, Crustaceans, Bivalves (Cole et al. 2015; Van Moos et al. 2012; Setälä al. 2016)
    Fish and Birds (Battaglia et al. 2016; Mazurais et al. 2015; Wilcox et al. 2015)
  - Trophic transfer is also demonstrated
    Within the plankton food web (copepods -> mysids, Setälä et al. 2014)
    Within the benthic food web (mussel -> crab , Farell & Nelson, 2013)
INTRODUCTION

 WHY do MP matter ?

• MP are everywhere

• MP are within the size range available prey

• MP have deleterious impacts
  - Physical damages/injuries (internal abrasion, blockages, Wright et al. 2013)
    (Alterations of tissue; Paul-Pont et al. in press)
  - Physiology (feeding rates, secondary production, reproduction)
    - copepods (Cole et al. 2014-2016)
    - bivalves (Sussarellu et al. 2016)
INTRODUCTION

✓ WHY do MP matter?

• MP are everywhere

• MP are within the size range available prey

• Can have deleterious impacts

• Facilitate chemical transfers

  Lu et al. (2016)
  Oliveira et al. (2013)
  Wardrobe et al. (2016)
INTRODUCTION

WHY do MP matter?

• MP are everywhere

• MP are within the size range available prey

• Can have deleterious impacts

• Facilitate chemical transfers

• Potential vectors to transport fouling / exotic rafting species / Pathogens

Carson et al. (2013)
Zettler et al. (2013)
Reisser et al. (2014)
INTRODUCTION

WHY do MP matter?

Colonisation of microplastics (PS, PMMA, PVC) vs. natural particles (chitin, silica) by the fluorescent Vibrio crassostreae J2-9 GFP strain

Colonisation of MP by V. crassostrea is favored and strengthened by aggregation

Foulon et al. (submitted)
ADVERSE EFFECTS ON PLANKTON COMPONENTS

- DELETERIOUS EFFECTS ON INGESTION AND SURVIVAL
- DELETERIOUS EFFECTS CAN BE LOWERED BY SEAWATER VISCOSITY
- CONCLUSION
ADVERSE EFFECTS ON PLANKTON COMPONENTS

DELETERIOUS EFFECTS ON INGESTION AND SURVIVAL

- Feeding mode: ‘non selective’ suspension feeder
- Size spectra of MPs ~ prey

Cole et al. (2013)

Lee et al. (2013)
ADVERSE EFFECTS ON PLANKTON COMPONENTS

DELETERIOUS EFFECTS ON INGESTION AND SURVIVAL

Cole et al. (2014, 2015, 2016)

Meioscool2016: a dive in a microscopic world – Plouzané (27th June – 1st July 2016)
ADVERSE EFFECTS ON PLANKTON COMPONENTS

DELETERIOUS EFFECTS ON INGESTION AND SURVIVAL

Decrease in ingestion (40% C biomass)
Shift in prey size

Cole et al. (2015)

Meioscool2016: a dive in a microscopic world – Plouzané (27th June – 1st July 2016)
ADVERSE EFFECTS ON PLANKTON COMPONENTS

- DELETERIOUS EFFECTS ON INGESTION AND SURVIVAL

Survival, Egg size, hatching success

Cole et al. (2015)
ADVERSE EFFECTS ON PLANKTON COMPONENTS

DELETERIOUS EFFECTS ON INGESTION AND SURVIVAL

**Egestion of MP**
- High Buoyancy of fecal pellets
- Low resistance to degradation

Impact on vertical transport (BCP)

Cole et al. (2016)
FROM ZOOPLANKTON TO FISH LARVAE

A typical marine food chain showing where the microbial loop links to the classic food web. Adapted from T. Fenchel (1988)
ADVERSE EFFECTS ON PLANKTON COMPONENTS

DELETERIOUS EFFECTS ON INGESTION AND SURVIVAL

PE beads (10-45 µm)
$10^4$-$10^5$ MP g$^{-1}$ food

22 dph Sea bass larvae

Sea bass (*Dicentrarchus labrax*)
from 7 to 45 dph

Impact on ingestion, growth and gene expression

European sea bass larvae from experimental group 10X at 20 dph containing three fluorescent Polyethylene microbeads (arrows) in its digestive tract. a: bright field; b: dark field. Scale bars represent 250 mm.

Mazurais et al. (2015)
ADVERSE EFFECTS ON PLANKTON COMPONENTS

DELETERIOUS EFFECTS ON INGESTION AND SURVIVAL

- PE beads (10-45 µm)
- \(10^4-10^5\) MP g\(^{-1}\) food

More beads \(\Rightarrow\) More ingestion
More Beads \(\Rightarrow\) More mortality (54% for \(10^5\) MP g\(^{-1}\) compared to controls)

\(~\) Gut obstruction
ADVERSE EFFECTS ON PLANKTON COMPONENTS

- DELETERIOUS EFFECTS ON INGESTION AND SURVIVAL

PE beads (10-45 µm)

$10^4 - 10^5$ MP g$^{-1}$ food

More beads $\Rightarrow$ More ingestion
More Beads $\Rightarrow$ More mortality (54% for $10^5$ MP g$^{-1}$ compared to controls)

$\sim$ Gut obstruction

More beads $\Rightarrow$ changes in gene expression

BUT

Marginal changes at the transcriptional level
Same growth (no energetic deficiencies) $\Rightarrow$ high egestion efficiency

Mazurais et al. (2015)
ADVERSE EFFECTS ON PLANKTON COMPONENTS

☒ DELETERIOUS EFFECTS ON INGESTION AND SURVIVAL

☐ DELETERIOUS EFFECTS CAN BE LOWERED BY SEAWATER VISCOSITY

☐ DISCUSSION & CONCLUSION
ADVERSE EFFECTS ON PLANKTON COMPONENTS

DELETERIOUS EFFECTS CAN BE LOWERED BY SEAWATER VISCOSITY

- Viscosity is fluid's resistance to flow.
  Internal friction of a moving fluid.

“The ability of a fluid to stick to itself”
**ADVERSE EFFECTS ON PLANKTON COMPONENTS**

- **DELETERIOUS EFFECTS CAN BE LOWERED BY SEAWATER VISCOSITY**

  - **Viscosity** is fluid's resistance to flow. Internal friction of a moving fluid.

  - Impacts physiological processes at small Reynolds numbers (Podolsky 1994; Bolton & Havenhand 1998, 2005)

  "Naganuma (1996)"
ADVERSE EFFECTS ON PLANKTON COMPONENTS

- DELETERIOUS EFFECTS CAN BE LOWERED BY SEAWATER VISCOSITY

- **Viscosity** is fluid's resistance to flow.
  
  Internal friction of a moving fluid.

- Impacts **physiological processes** at small Reynolds numbers
  

- Depends on
  
  **Seawater temperature** (Podolsky & Emlet 1993)
  
  Biopolymers, Macromolecules and Proteins (Qin et al. 2015) –
  
  **phytoplanктон**
ADVERSE EFFECTS ON PLANKTON COMPONENTS

- DELETERIOUS EFFECTS CAN BE LOWERED BY SEAWATER VISCOSITY

Foam formation induced by *P. globosa* bloom (eastern English Channel)

*Meioscool2016: a dive in a microscopic world – Plouzané (27th June – 1st July 2016)*
ADVERSE EFFECTS ON PLANKTON COMPONENTS

- DELETERIOUS EFFECTS CAN BE LOWERED BY SEAWATER VISCOSITY

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- Depends on Seawater temperature (Podolsky & Emlet 1993)
  Biopolymers, Macromolecules and Proteins (Qin et al. 2015) – phytoplankton

Can viscosity lower MP contamination by zooplankton?

Seuront & Vincent (2008)
ADVERSE EFFECTS ON PLANKTON COMPONENTS

DELETERIOUS EFFECTS CAN BE LOWERED BY SEAWATER VISCOSITY

- 10 µm
- 15 µm
- 20 µm

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ADVERSE EFFECTS ON PLANKTON COMPONENTS

- DELETERIOUS EFFECTS CAN BE LOWERED BY SEAWATER VISCOSITY

Tests (Copepods + MP + Ficoll)

Controls (Copepods + MP)

20% Increase in viscosity
ADVERSE EFFECTS ON PLANKTON COMPONENTS

- Deleterious effects can be lowered by seawater viscosity.

![Graph showing the effect of particle size on ingested MP copepods.](graph.png)
**ADVERSE EFFECTS ON PLANKTON COMPONENTS**

- **DELETERIOUS EFFECTS CAN BE LOWERED BY SEAWATER VISCOSITY**

  - Feeding current > Viscosity
  - Viscosity > Feeding current

  **Viscosity does lower MP ingestion**

  - Viscosity level
  - MP size

*Meioscool2016: a dive in a microscopic world – Plouzané (27th June – 1st July 2016)*
Adverse Effects on Plankton Components

Deleterious effects can be lowered by seawater viscosity

Viscosity does lower MP ingestion

Seuront et al. (2006)
Viscosity can increase up to 250%

Good news for zooplankton

But…..
ADVERSE EFFECTS ON PLANKTON COMPONENTS

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Good news for zooplankton

BUT.....

BAD news for the Benthos

Long et al. (2015, submitted)
ADVERSE EFFECTS ON PLANKTON COMPONENTS

Research on MP are increasing ~ MP pollution
- increase in awareness
- increase in technical devices and sampling efforts

Challenging issues
- Concentrations
- Types of MP (spherical beads, composition)
- Nanoplastics

Review

Is there any consistency between the microplastics found in the field and those used in laboratory experiments?☆

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ADVERSE EFFECTS ON PLANKTON COMPONENTS
ADVERSE EFFECTS ON PLANKTON COMPONENTS

Perspectives

Why in some cases MP are chosen or avoided?

to better understand selectivity mechanisms against microplastics

Trophic transfer in the plankton webs?

to assess whether copepods are efficient MP vectors and their impact on higher trophic levels (e.g. gut obstruction?)

What about your bugs?
THANK YOU