Plastics and Us!
Sources, Pathways and Mitigation

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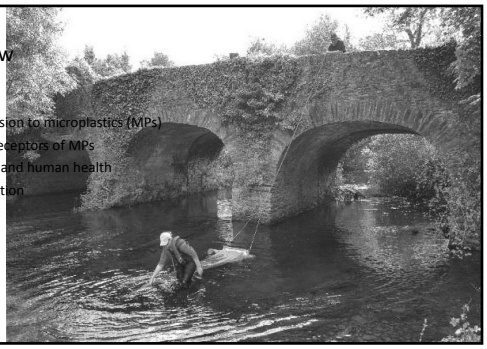
Overview



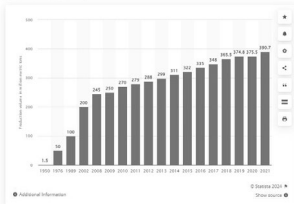
- Plastics: Conversion to microplastics (MPs)
- Pathways and receptors of MPs
- Impact to biota and human health
- Potential mitigation

Plastics

Chemicals & Resources › Plastic & Rubber

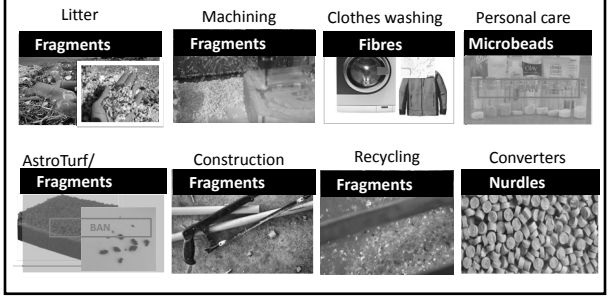
Annual production of plastics worldwide from 1950 to 2021

(in million metric tons)

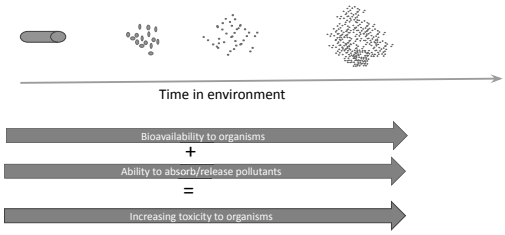


- 400 million metric tonnes per year (Statistica, 2024)
- Over a million tonnes of plastic waste per year from different sources (Pathak & Navneet 2017).
- Advantages: light weight, durable and inexpensive to manufacture

Conversion to Microplastics



Degradation of plastics -They don't fully break down!!

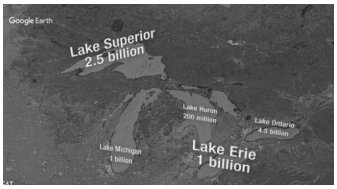


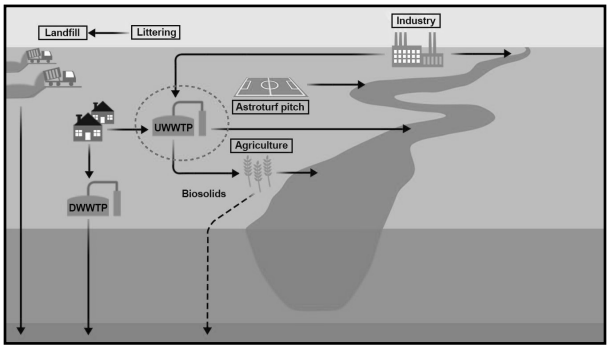
The Guardian , August 2023

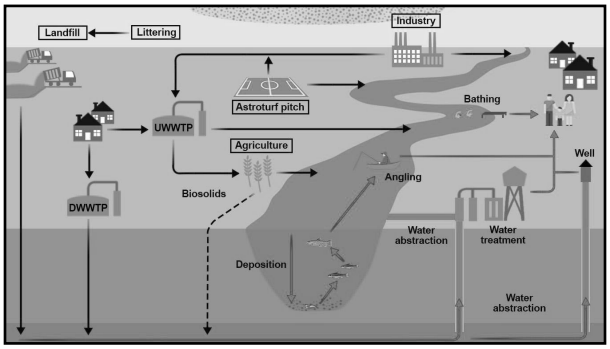
90% of Great Lakes water samples have unsafe microplastic levels - report

But experts say damage can be reversed if US and Canada act quickly to stop new plastics from entering lake system

Microfibers that come off clothing in washing machines are a common source of microplastic pollution. Photograph: a-ts/Alamy

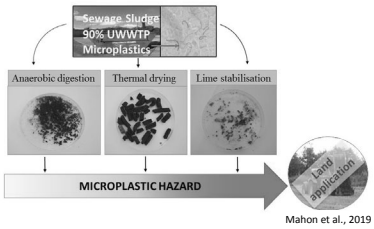






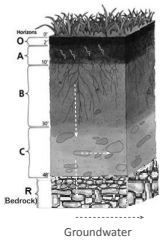
Pathways- Land application via waste treatment

- MPs concentrated in sewage sludge and then applied to land



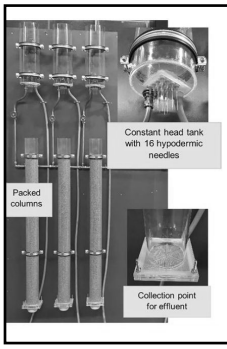
Mahon et al., 2019

Agricultural land - Source, Pathway and Sink?



Factors influencing pathways of MPs on soil

- Nature of MPs (size shape)
- Hydrogeology- Bedrock type, aquifers etc
- Slope of the land
- Climate and weather (temperatures, UV intensity rainfall regimes
- Presence of ditches and streams
- Rototilling
- Biological make-up of the soil



Vertical migration Lab experiment

Experimental Set-uP

- Glass, sand and ceramic media
- Virgin MPs

(<0.15mm and 0.15–0.3mm)

Results

- MPs remained static at the surface
- No vertical translocation

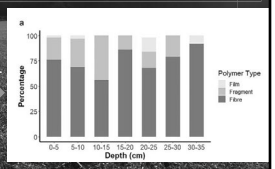
However…. How would this compare to the field with weathered MPs?

Field study on vertical translocation

- Sites with long history of spreading and current rototilling
- 2m deep cores
- Geochemical stratigraphy using Itrax XFR scanner

Field study on vertical translocation -Results

- First 25cm- loamy texture with lower levels of compaction
- First 35cm- MPs were reasonably well distributed.
- Up to 2103 MP/KG with fibres penetrating deeper



Conclusions: Ploughing likely to be driver of vertical migration

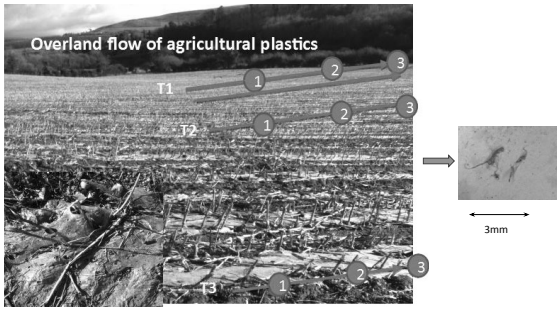
Some other studies Have found MPs deeper

Depth (cm)

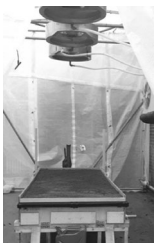
Cao et al., 2021

Webber et al., 2022
Tagg et al., 2022

Li et al., 2022



Pathways…Overland flow of MPs



Lab experiment

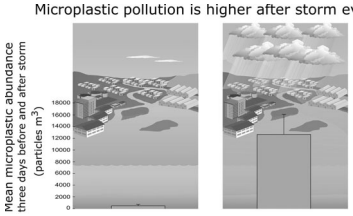
- Rainfall regimes, 8 mm h-1 and 18 mm h-1

Findings

- Slope less influential than rainfall intensity
- Impact of rainfall intensity was reduced with grass
- Low density MPs (PP) move further than heavier ones (HDPE, PVC)

Several studies have shown that rainfall is a key driver in mobilising MPs across the surfaces

Microplastic pollution is higher after storm events

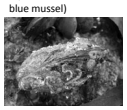


(e.g. Crossman et al., 2020; Hitchcock, 2020).

Impacts to aquatic systems

Impacts to aquatic biota

Mytilus edulis (edible blue mussel)



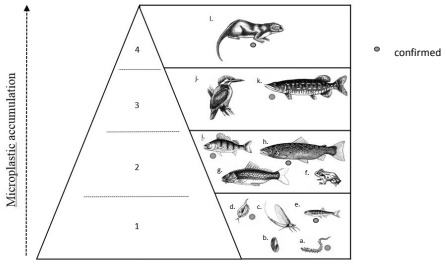
Inflammation- cross over to circulatory system

Common Gobi

Confusion with prey items
Reduced fitness affecting predatory Performance,
Sá et al., 2015

Short-tailed shearwater

Gut transfer of PBDE (polybrominated diphenyl ethers) flame retardants from plastic material to fatty tissue
Tanaka et al., 2013



Impact to Humans-Largely unknown

- Leaching of plasticisers into liquids
- Effects of additives- largely unknown
- Ingestion of microplastics into the lymphatic system
- Cellular penetration is possible in the nanometer size range!
- Interactions between microplastics and fluids present in the gut may impact on immune system

Hussain and Jaitley, 2001, Bouwmeester et al., 2015, Powell et al., 2007)

What can be done?

Clean-up activities to remove the waste, as high as US$15 billion per year.

Prevention

- Reduce use

Mitigation

- Reuse use where possible (deposit return schemes)
- Capture outputs from Industry (process changes, filters)
- Reduce littering (how did the litter get on the beach or in the water?)
- Recycle where possible… not always available
- Biodegradable solutions

Environmental Biodegradation of plastics

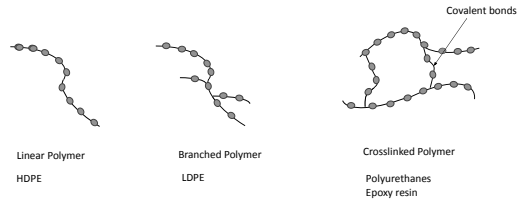
Stage 1. Bio-deterioration
Mechanical, chemical and physical properties of plastics are altered

Stage 2. Bio-fragmentation
The breaking down of plastics into smaller molecules
Microplastics

Stage 3. Ultimate biodegradation
Assimilation by microorganisms = H_2O and CO_2 (aerobic conditions)

- Environmental factors
- Microbial activity
- Physical activity
- Structure and constituents of plastic

Polymer chain topology



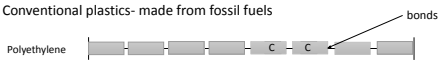
Linear Polymer
HDPE

Branched Polymer
LDPE

Crosslinked Polymer
Polyurethanes
Epoxy resin

Structure- nature of linkages

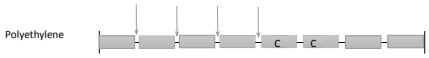
- Conventional plastics- made from fossil fuels



- Bioplastics made from renewable sources: Algae, cellulose, bacteria, starch.

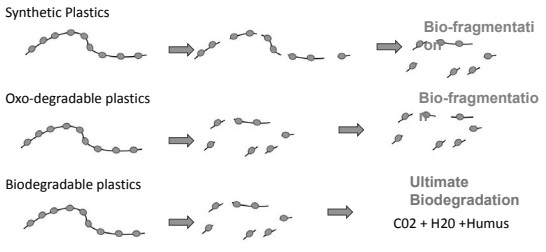
Glycosidic linkage

Oxo-Degradable

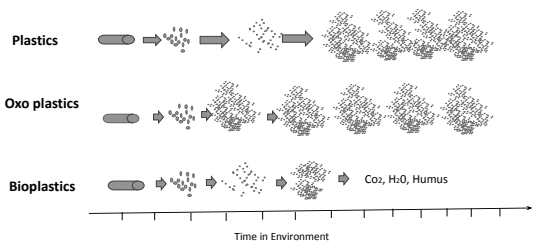


Stage 1. Bio-deterioration → **Stage 2. Bio-fragmentation =** Microplastics

Degradation or fragmentation?

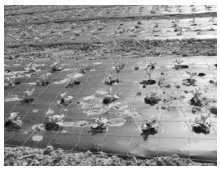


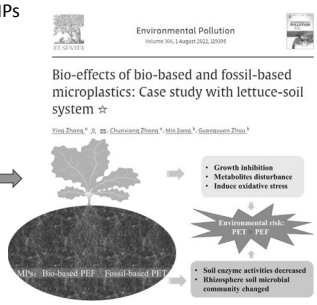
Plastics, Oxo-plastics and Bioplastics over time



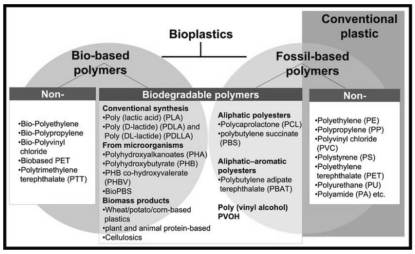
Synthetic MPs Vs Biobased MPs

- More friendly interaction with plants and soil





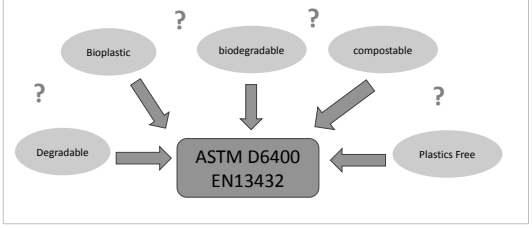
Slightly confusing…….



Bhagwat et al., 2020

Labelling and standards

Look for compostable labelling and compliance with standards



What plastics to use?

Conventional plastics	Biodegradables
More recyclable	Less recyclable ✗
Better known	Less known ✗
Non-compostable ✗	Compostable
Persist longer in the environment ✗	Persist less time in the environment
More toxic in the environment ✗	Less toxic in the environment

More potential for reuse for short term use?

Less impact for long term use

Risk assessments for those working with plastics, for example erosion control

Likelihood	Consequence				
	1: Negligible	2: Minor	3: Moderate	4: Significant	5: Major
1: Rare	1	2	3	4	5
2: Unlikely	2	4	6	8	10
3: Possible	3	6	9	12	15
4: Likely	4	8	12	16	20
5: Almost certain	5	10	15	20	25

- Important populations of protected species

Risk rating: green, low; yellow, medium; orange, high; red, very high.

Factors to consider

- Duration of plastic item in environment
- Proximity to water
- Slope

Table 5.8. Potential microplastics risk categories for some protected species listed in the Habitats Directive (HD), the Birds Directive (BD) and the Red List

Protected species	Low	Medium	High	Very high
Lake orb mussel (*Musculum lacustre*) (VU)	X			
Sand-bowl amber snail (*Quickella arenaria*) (EN)	X			
Swan mussel (*Anodonta cygnea*) (VU)				
Swamp orb mussel (*Sphaerium nucleus*) (VU)		X		
Desmoulin's whorl snail (*Vertigo moulisiana*) (HD)		X		
Freshwater pearl mussel *Margaritifera margaritifera*) (HD)			X	
Nore freshwater pearl mussel (*Margaritifera durrovensis*) (HD)			X	
River lamprey (*Lampetra fluviatilis*) (HD)		X		
Brook lamprey (*Lampetra planeri*) (HD)		X		

Mahon et al., 2017

Legislative pressures on use of plastics

- Microbeads: The Microbead-Free Waters Act of 2015
- Single use plastics ban (2021, 2022)
- Rubber crumb infill ban, Europe (September 2023)
  ⇩
  Industry has to clean-up and document disposal of MPs
- Provisional agreement to amend EU Directive 2005/29 on unfair commercial practices Directive (January 2024)

Other wildlife protection directives

- EU habitats directive
- EU Water Framework Directive
- EU Birds Directive

Thank you!

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