

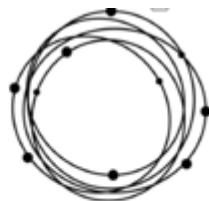


# Plastics and the circular economy

Tamara Galloway

**EPSRC**

Engineering and Physical Sciences  
Research Council

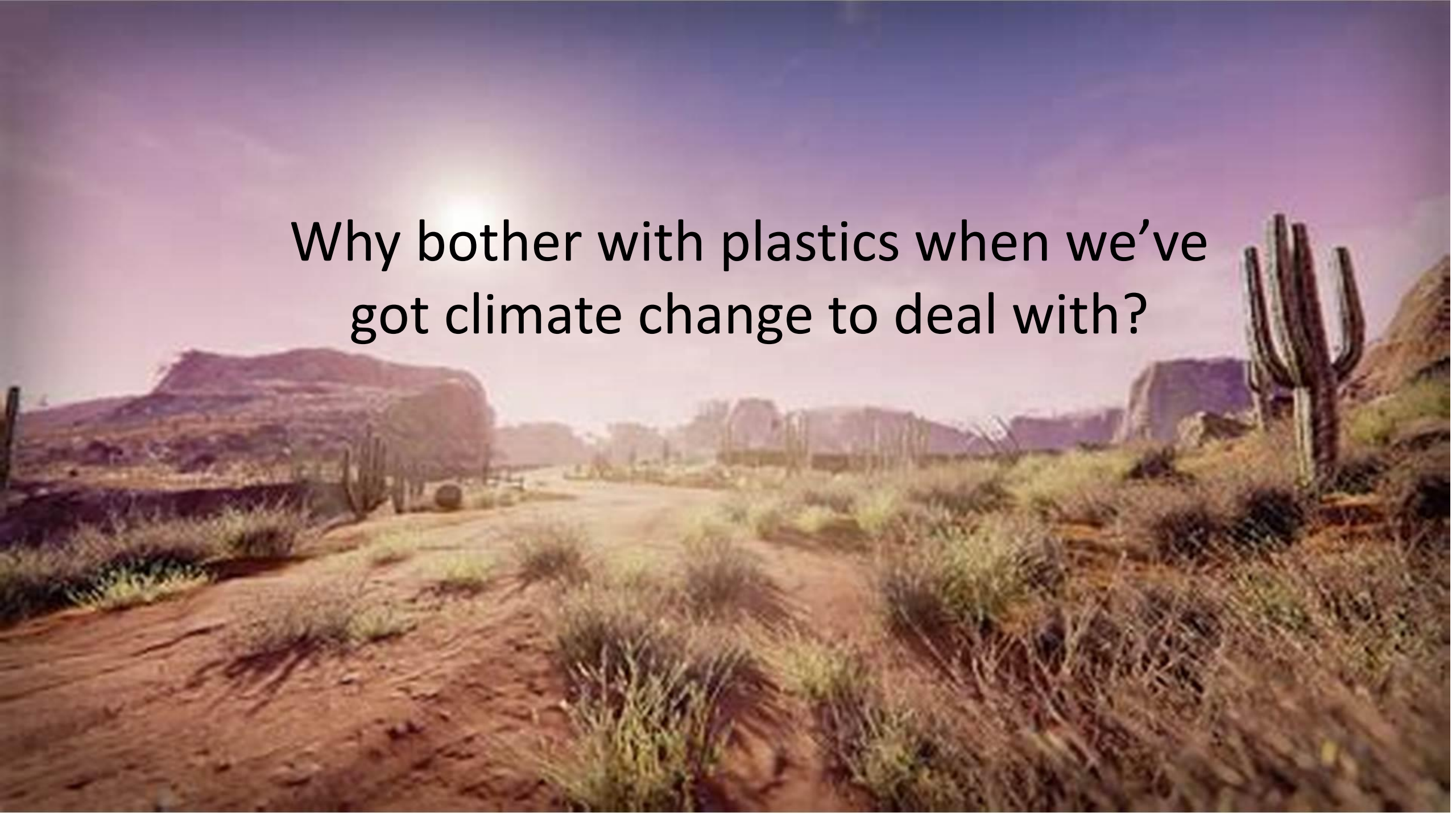


ExeMPLaR

<https://www.exeter.ac.uk/gsi/>

UNIVERSITY OF  
**EXETER**

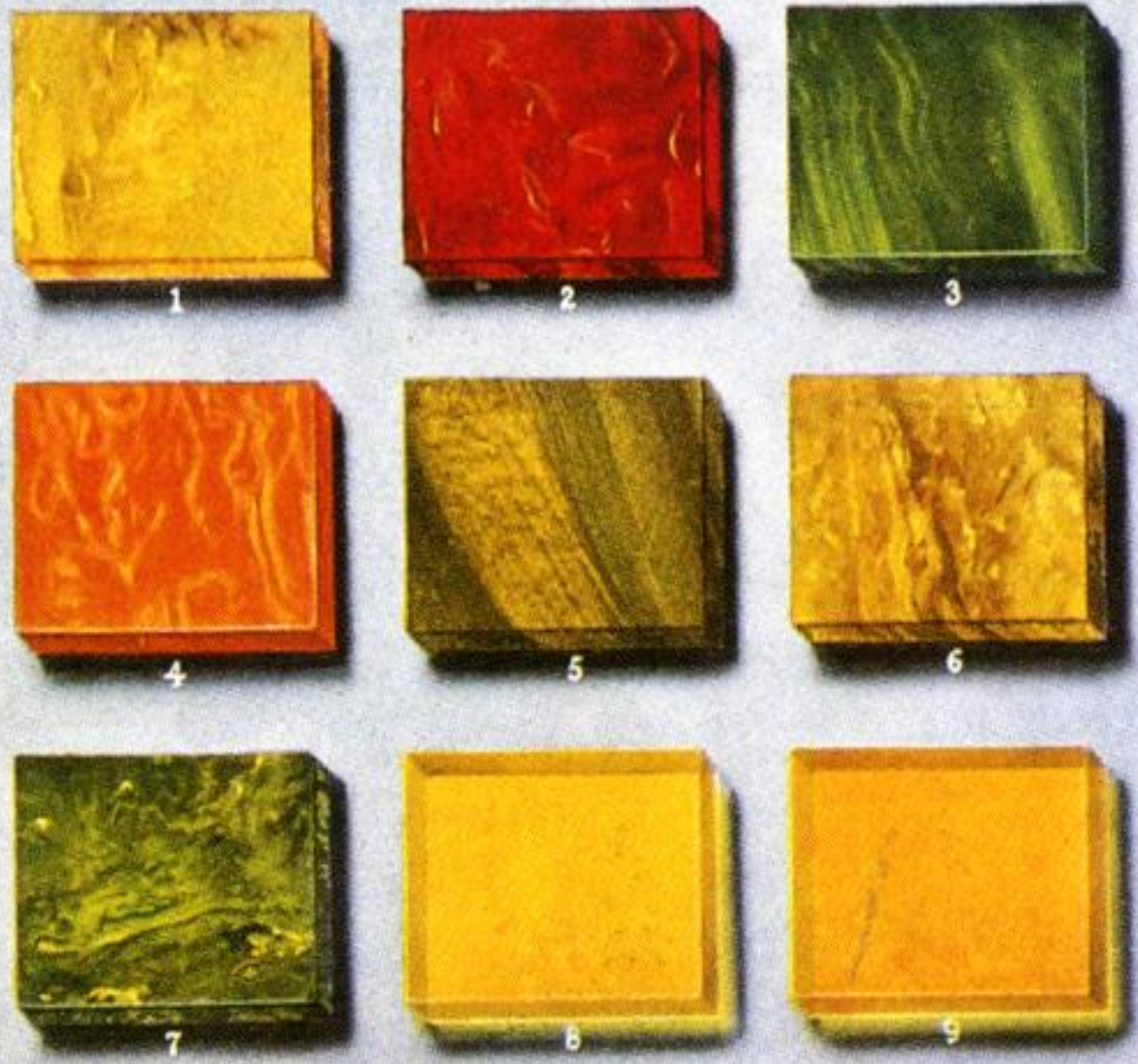
Why bother with plastics when we've got climate change to deal with?



1907



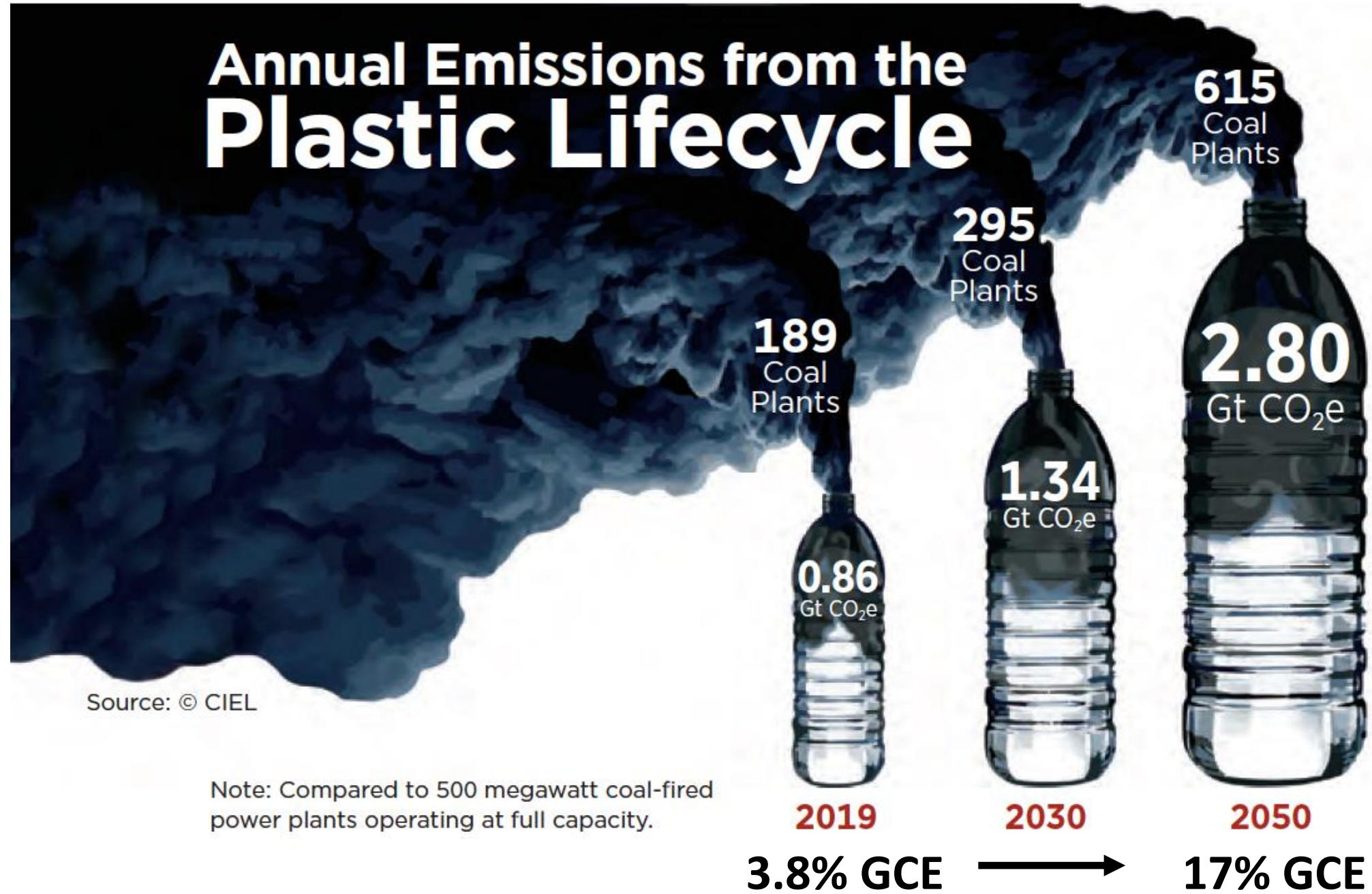
**NEW BAKELITE JEWEL QUALITY COLORS**



1990s



# Annual Emissions from the Plastic Lifecycle



# What do we design plastic for?

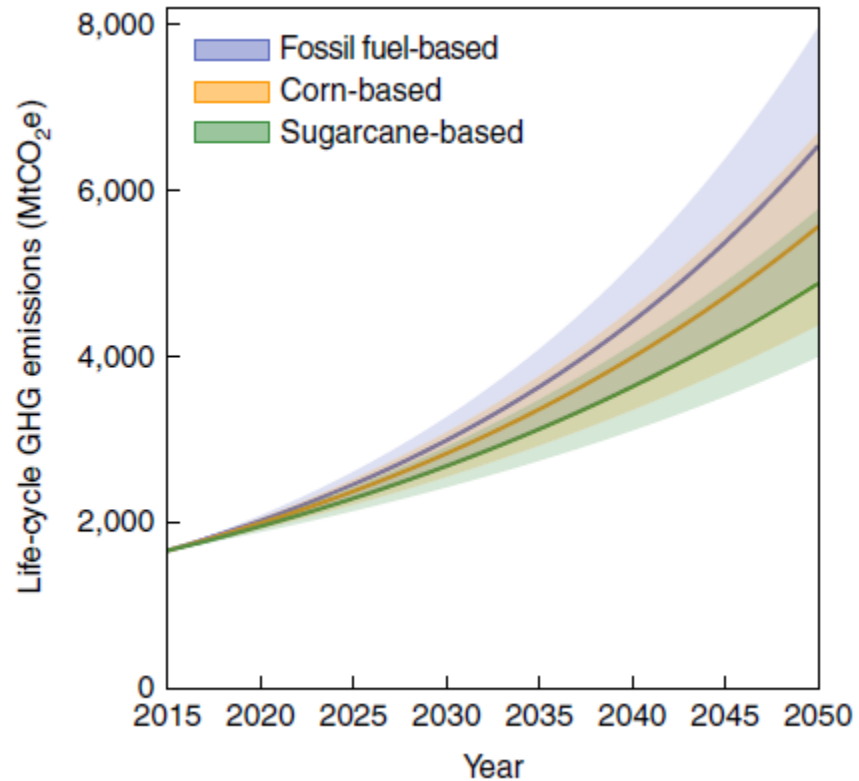


# Circular economy

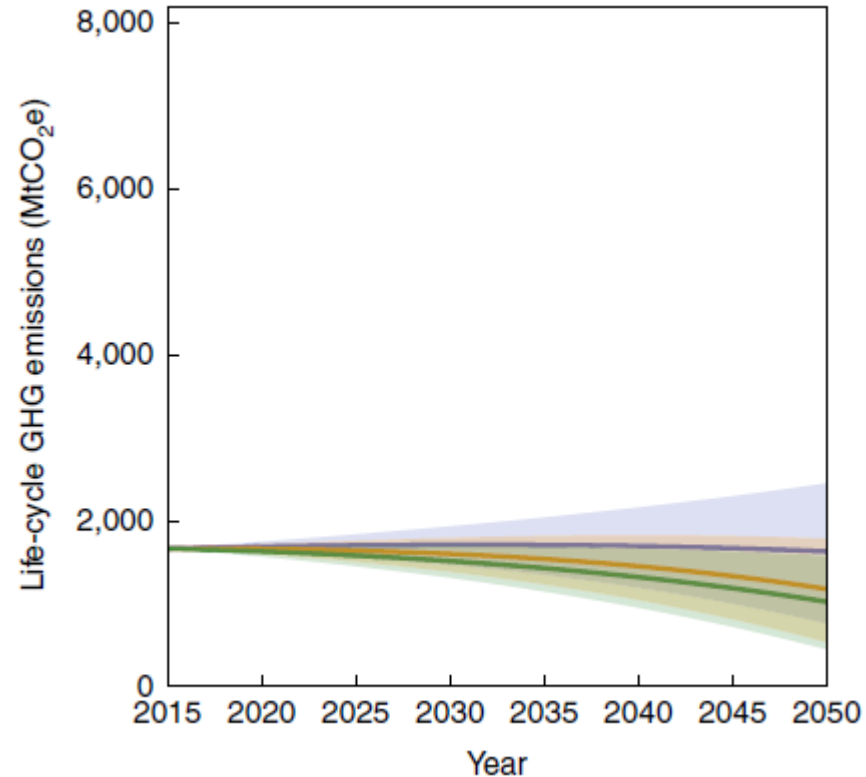
- Design out waste and pollution
- Keep materials and products in use for longer
- Regenerate natural systems



# Go circular to decarbonise the system!



Current system  
4% growth pa



Circular system: renewable  
energy, bio-based feedstocks,  
recycle and reuse





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# The ExeMPLaR Project

A Circular Economy where plastics never become waste.

[Get Involved.](#)

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Research Council

[www.exemplarnet.org.uk](http://www.exemplarnet.org.uk)

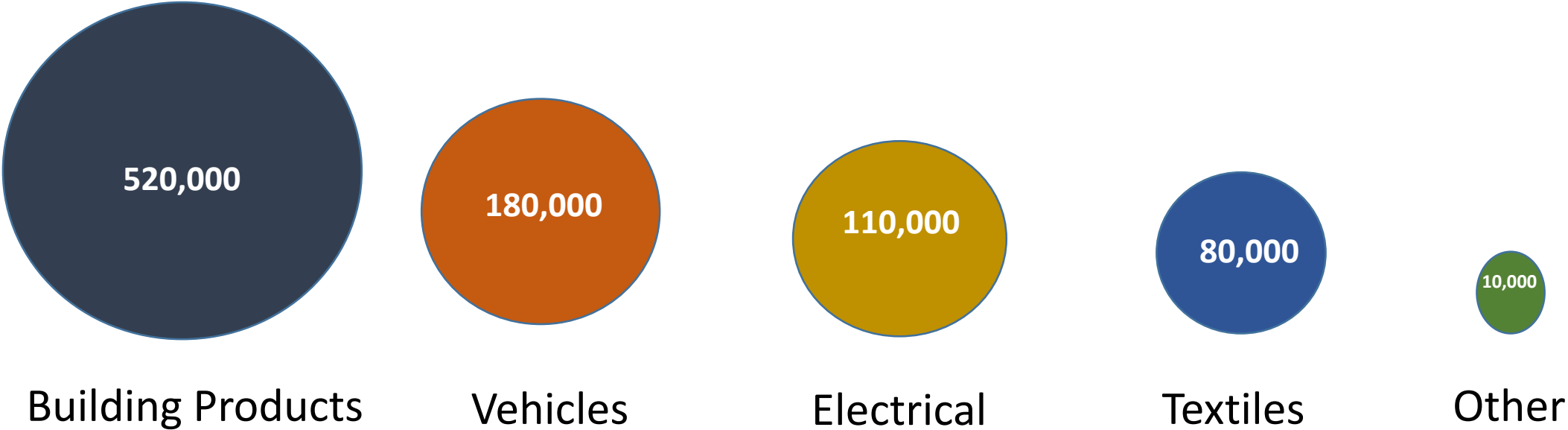
# Creating regional circular economy resource flows



- Economists
- Sociologists
- Life cycle assessment modellers
- Engineers
- Ecotoxicologists
- Industrial, NGO, civic partners



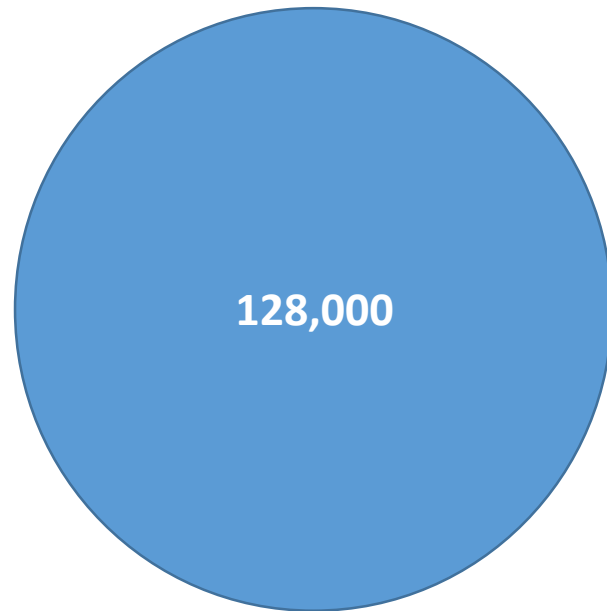
# Stocks of household plastics in South West households (t)



(Not to scale)



# Three illustrative annual flows of plastic waste in the South West Region (t)



**Household  
Domestic**



**Fishing  
gear**

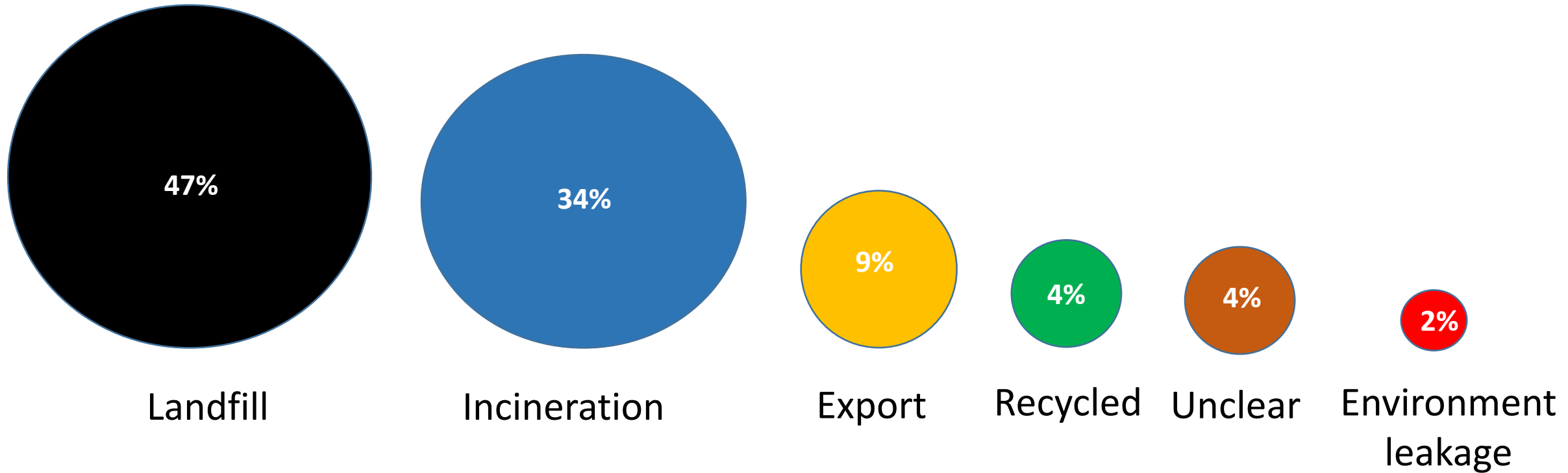


**Agriculture**

(Not to scale)



# Fate of household plastic waste in South West Region (%)



(Not to scale)



# Creating a future regional plastic circular economy



Problem



Impact



Solution

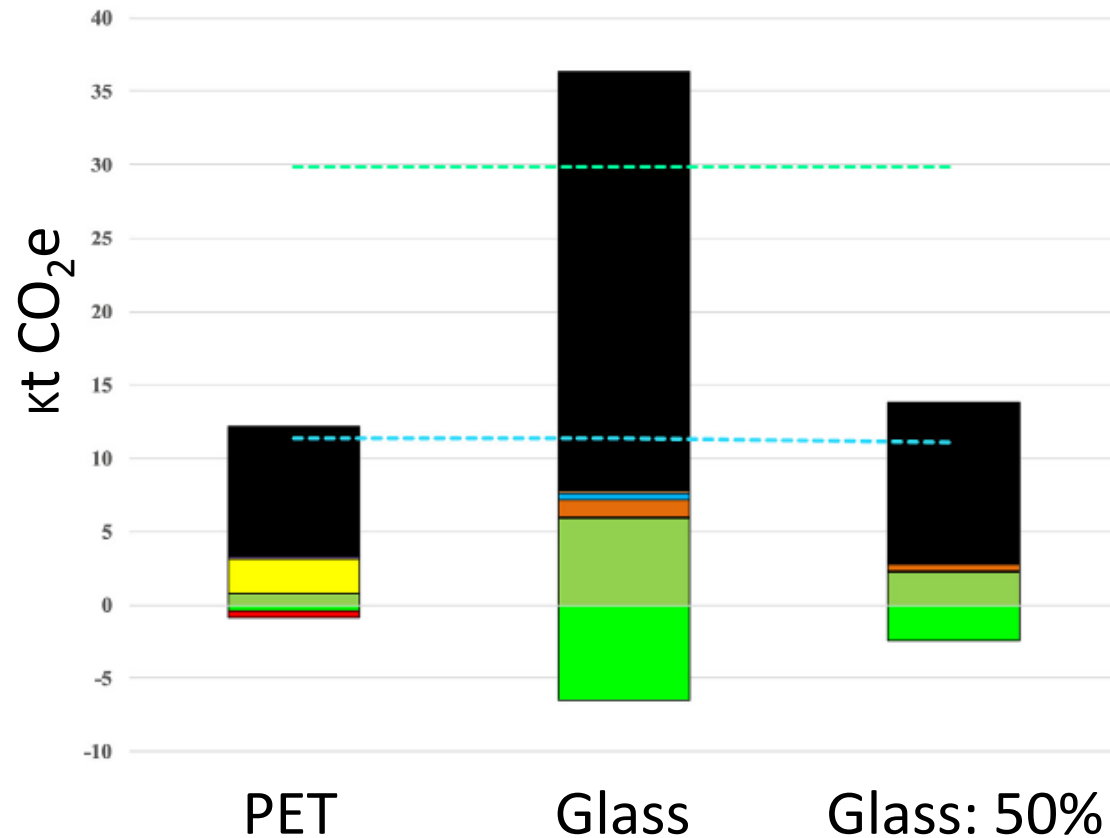


Economic Opportunity

- Life cycle modelling
- Human health evidence synthesis
- Ecotoxicity testing



# LCA: Comparative global warming potential for PET or glass bottles

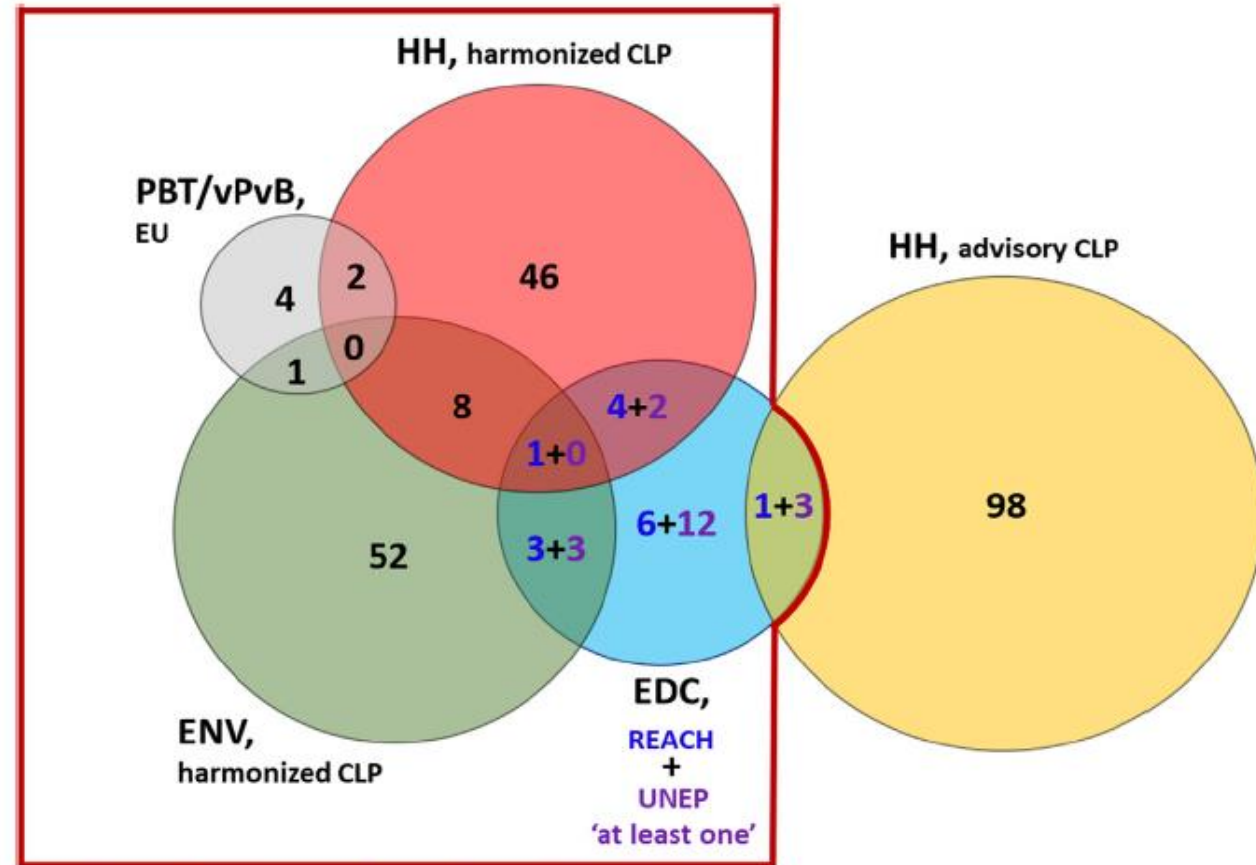


Replacing PET with glass would **double** global warming potential. unless glass were made 50% lighter

# Evidence synthesis: high risk chemical additives in a circular economy context:



- *likelihood of impact by recycling processes?*
- *frequency of use in primary plastic products (virgin inputs)?*
- *human health hazard score?*
- =6/6 top scoring substances were phthalates



List of 148 most hazardous chemicals

Groh et al 2018



# Bioplastics



- Sustainably derived (seaweed)
- biodegradable
- decouples plastics from the oil industry



- Inferior performance
- cost
- unknown ecological effects



# Recycled plastics



- 5.4 million cups reused
- potentially replacing 17 billion single use cups



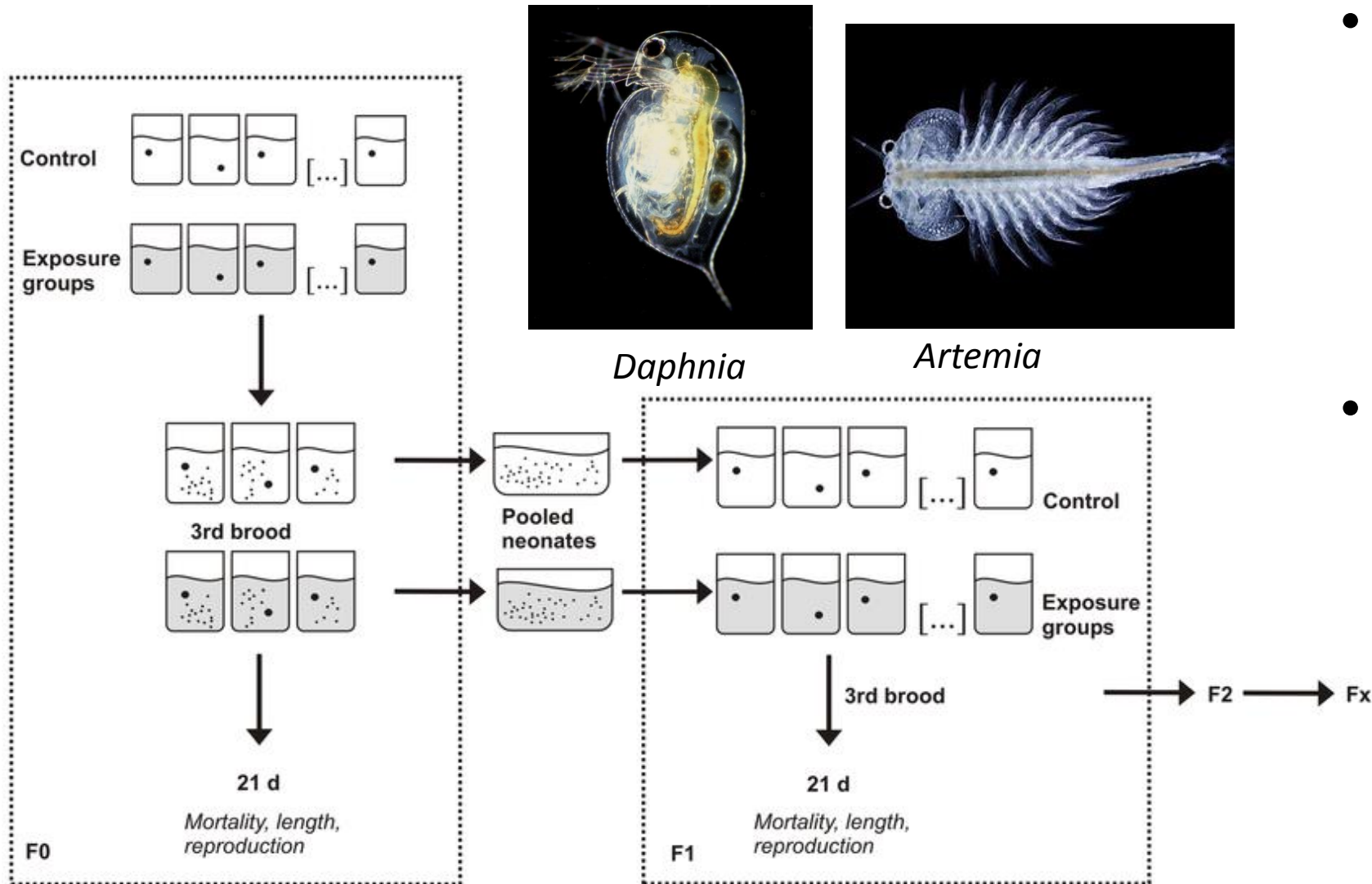
- Reduced mechanical performance
- molecular degradation
- contamination



# Ecotoxicity test panel



- Acute
- Chronic
  - growth, survival, reproduction, stress response, oxidative damage, metabolic effects
- Multigenerational



# Test plastics across the lifecycle



- Microplastics
- leacheates
- mixtures: cadmium, fluoranthene

| item             | lifecycle stage      | category    | exposure    | circularity |
|------------------|----------------------|-------------|-------------|-------------|
| vPET             | polymer (flakes)     | fuel-based  | leachate    |             |
| rPET             | polymer (flakes)     | fuel-based  | leachate    | ++          |
| tritan           | polymer (flakes)     | fuel-based  | leachate    |             |
| vPP              | polymer (flakes)     | fuel-based  | leachate    |             |
| vPP              | use (coffee cup)     | fuel-based  | leachate    |             |
| rPP/rpaper       | use (coffee cup)     | fuel-based  | leachate    | ++          |
| rPP/GF           | polymer (flakes)     | fuel-based  | leachate    | ++          |
| neoprene         | use (wetsuit)        | fuel-based  | leachate    |             |
| fish gelatine I  | use (food packaging) | bioplastics | solubilized | +++         |
| fish gelatine II | use (food packaging) | bioplastics | solubilized | +++         |
| pork gelatine I  | use (food packaging) | bioplastics | solubilized | +++         |
| pork gelatine II | use (food packaging) | bioplastics | solubilized | +++         |
| algae            | use (food packaging) | bioplastics | solubilized | +++         |

(not published yet, please do not share)



Small pieces

Freeze-grinding

Dry-sieving  
50-400 µm

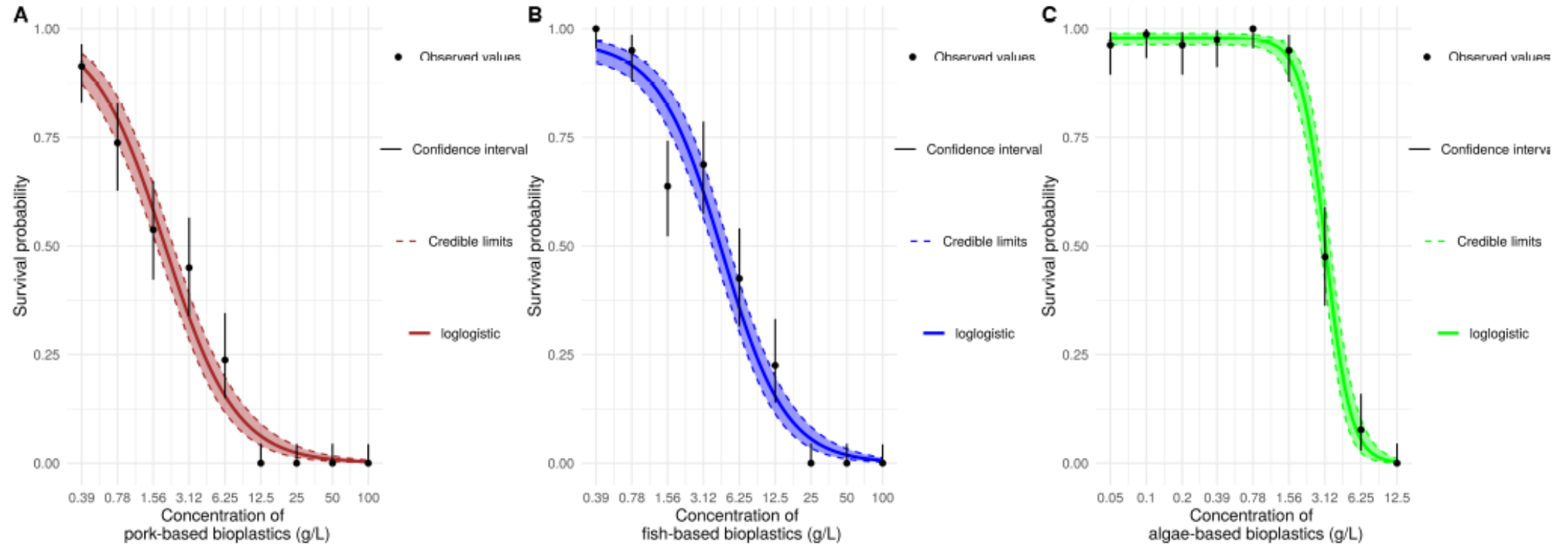
**1g:10 ml**  
ratio

48h  
overhead  
rotation

0.2 µm  
filtration

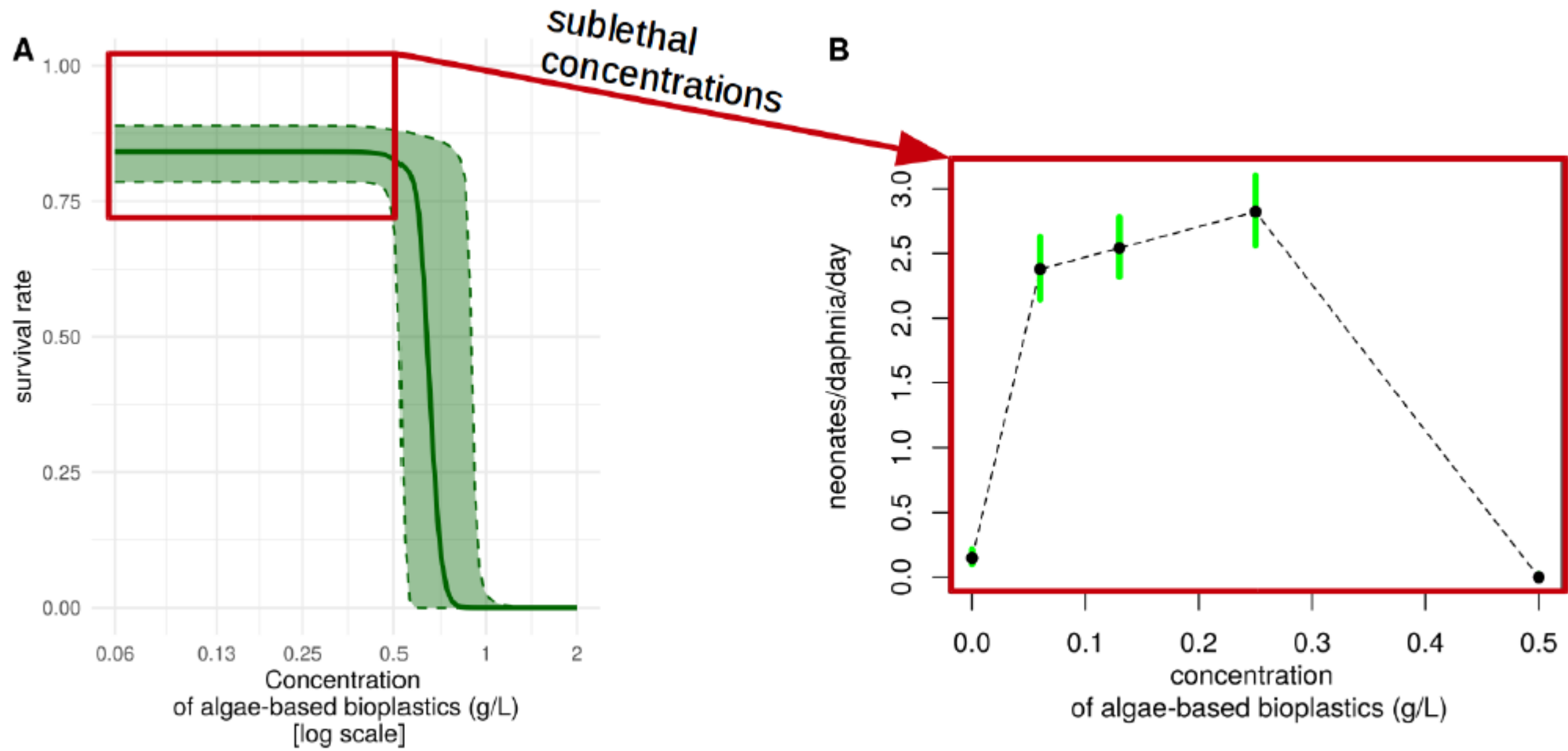


# Results: Biopolymers show low toxicity

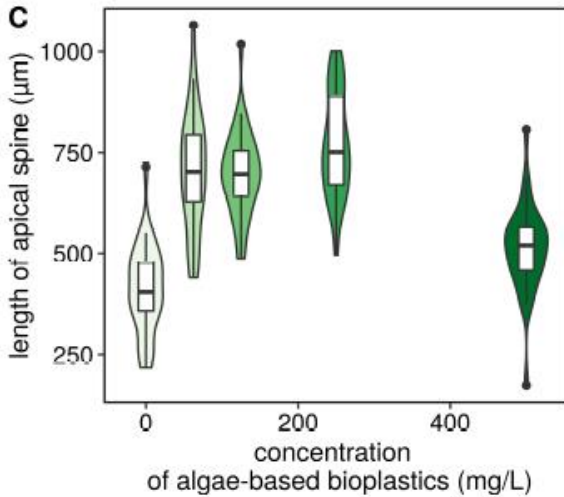
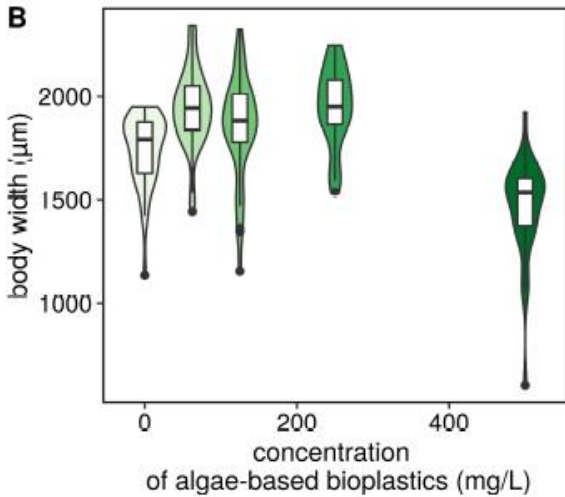
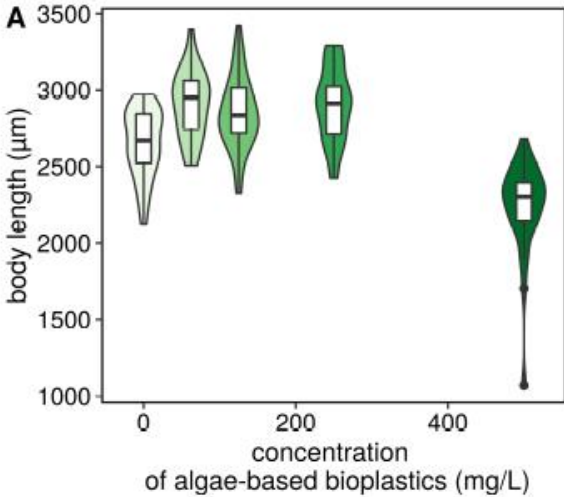
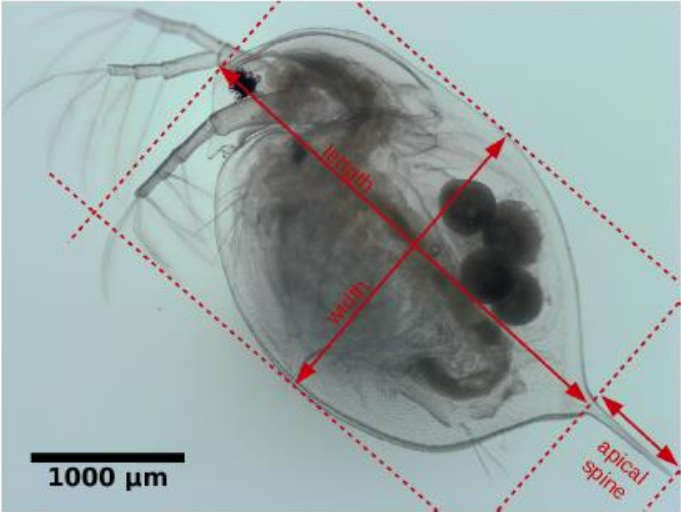


LC10, LC50 in the g/L range

# Growth promoting effects

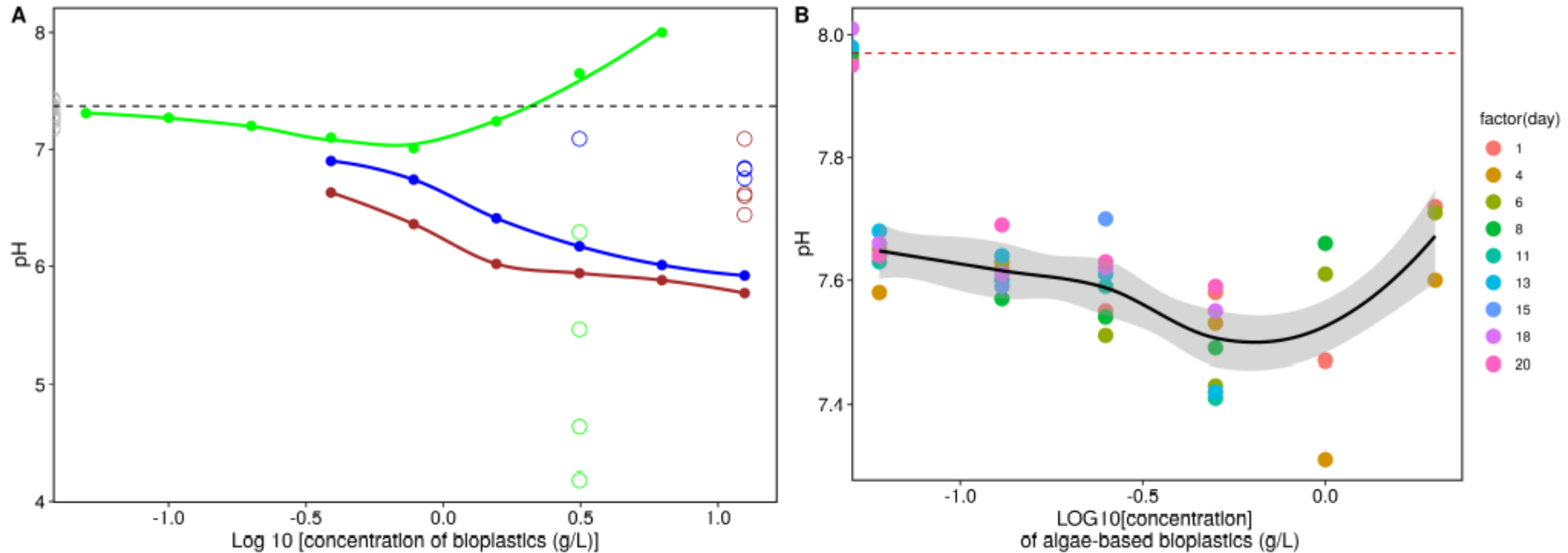


# Biometric analysis





# Altered water chemistry



- Currently - 99% petrochemical: 1% biopolymer
- 2030 EU target - 35% petrochemical: 65% biopolymer



# Conclusions

- Creating circular economy-inspired solutions for plastics is a multi-layer, multi-scale challenge
- There is no single answer



Vintage Bakelite telephone

# Acknowledgements

- Paul Boisseaux + all in the ecotoxicology group
- Peter Hopkinson
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- Jaqualine Earles
- Ruth Garside



<https://www.exeter.ac.uk/gsi/>

