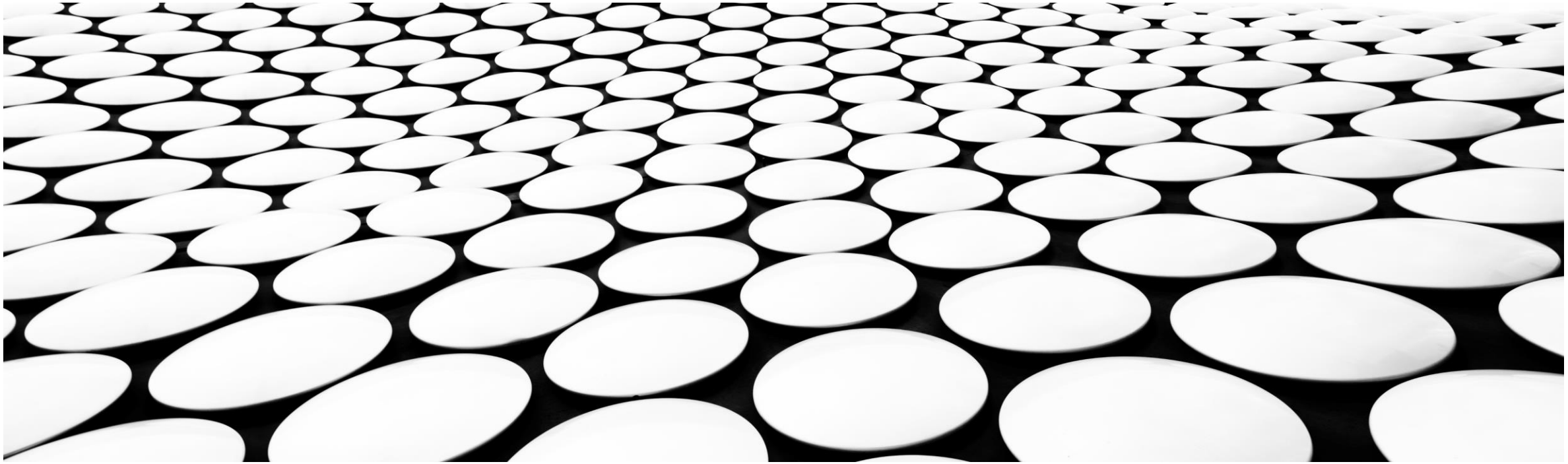
BIODEGRADABLE MICROCAPSULES

JULY 2022

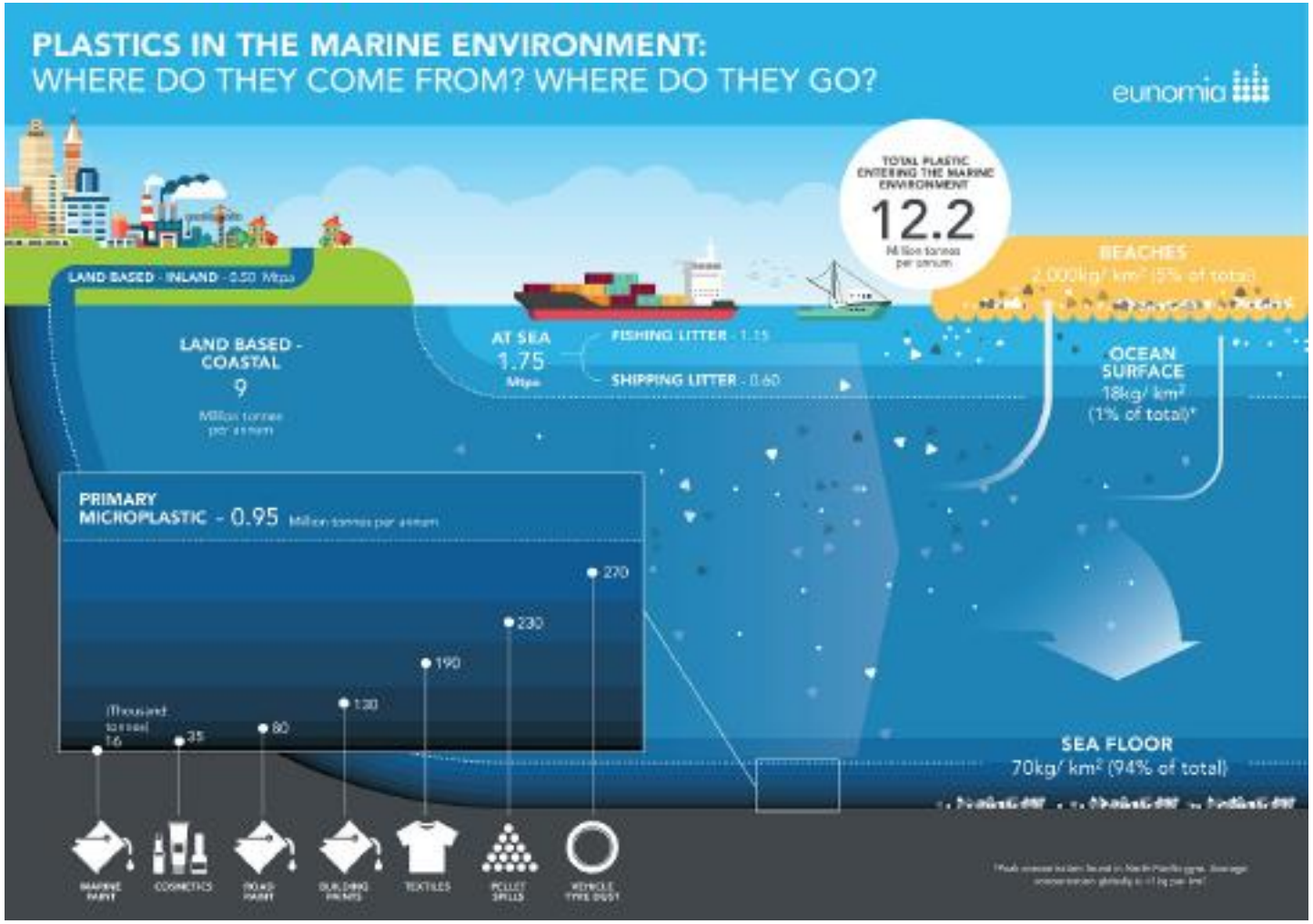


AGENDA

- The Need for Biodegradable Microcapsules
- Relevant Applications
- Key Success Criteria
- Solution Providers
- Trucapsol’s approach
  - Biodegradability
  - Laundry Performance
  - Leakage Stability

THE NEED

- Unmanaged plastic waste enters the envrironment through various channels
- Majority of plastics are not biodegradable, they will remain in the environment for hundreds of years
- Microplastics are described as insoluble solid polymers less than 5 mm in dimensions that persist in the environment
- Since we cannot recover microplastics, the best strategy is to design biodegradable alternatives

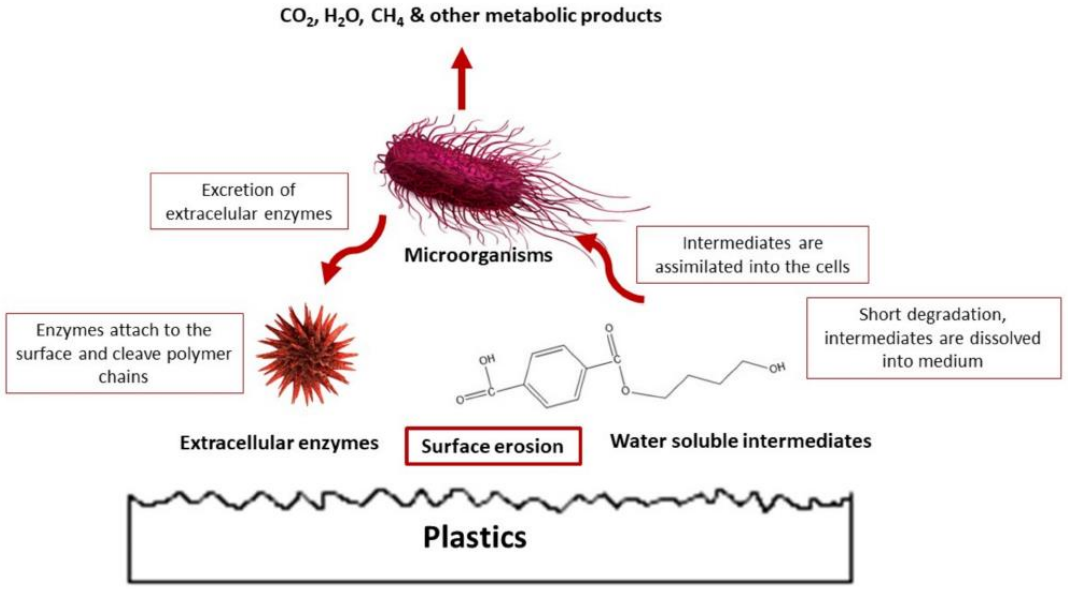


ECHA REGULATION

- NGO, public concerns, and national efforts by individual countries in Europe triggered ECHA regulation
- Intentionally added microplastics constitute approx. 400,000 tons of microplastic litter
- Microplastic Definition:
  - particles containing solid polymer, to which additives or other substances may have been added, and where ≥ 1% w/w of particles have (i) all dimensions 0.1µm ≤ x ≤ 5mm, or (ii), for fibres, a length of 0.3µm ≤ x ≤ 15mm and length to diameter ratio of >3
  - Shall not be placed on the market as a substance on its own, or in a mixture, as a microplastic in a concentration equal to or greater than 0.01% w/w

BIODEGRADABILITY EXEMPTION

- Test material can be considered to be biodegradable, and therefore exempted from the regulation, if it passes criteria at any level
  - OECD Ready Biodegradation : > 60% degradability after 28 adys
  - OECD Enhanced Ready biodegradation : > 60% degradability after 60 days
  - OECD Inherent Biodegradation : >70% mineralization within 14 days
  - ISO Media-Specific Studies (soil, freshwater, marine sediment)
  - OECD Degradation Simulation Studies (realistic environment – soil, freshwater, marine sediment)



Important Concerns

1) Kinetics of degradation
2) Toxic by-products
3) Microbial diversity in different regions
4) Type of wastes processed by facility

Teixeira, S.; Eblagon, K.M.; Miranda, F.; R. Pereira, M.F.; Figueiredo, J.L. Towards Controlled Degradation of Poly(lactic) Acid in Technical Applications. *C* **2021**, *7*, 42

RELEVANT APPLICATIONS

- Personal Care – fragrance capsules
- Household Care – fragrance capsules
- Agriculture – controlled release nutrients
- Paints & coatings – latex emulsions

- ➔ let’s focus on the fragrance capsules

KEY SUCCESS CRITERIA FOR FRAGRANCE CAPSULES

- Unencapsulated Oil
  - Controls consumers' first interaction with product
- Leakage stability in product (aged 4wk/40C)
  - Assures that the technology can survive supply chain
- Laundry fabric odor performance
  - Assures in-use performance of the technology
- OECD 301 Biodegradability > 60%
  - End-of-cycle degradation of the technology

SOLUTION PROVIDERS

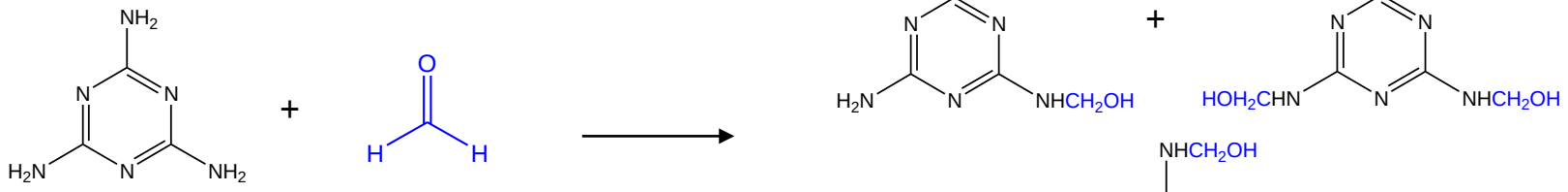
- Specialty Chemical Companies that provide encapsulation solutions
  - BASF
  - Encapsys
  - Calyxia
  - Trucapsol !!
  - Microtek
  - Capsulae
  - Aveka
- Perfume houses (incentive is to sell more fragrance)
  - Firmenich
  - Symrise
  - Givaudan
  - International Flavors & Fragrances
  - Takasago

MARKET CAPSULES

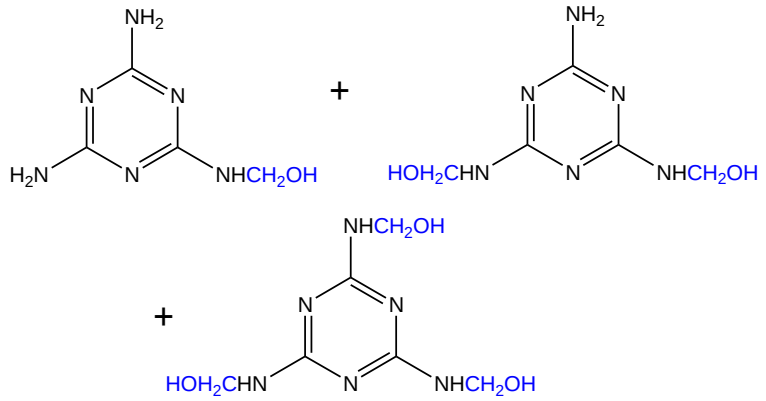
- Melamine-Formaldehyde / Melamine-Glyoxal
  - Acid-catalyzed polycondensation
- Polyacrylates
  - Free radical polymerization
- Polyisocyanate-amine
  - Acid-Base interfacial polymerization

Melamine Derived Perfume Microcapsules

Pre-condensate

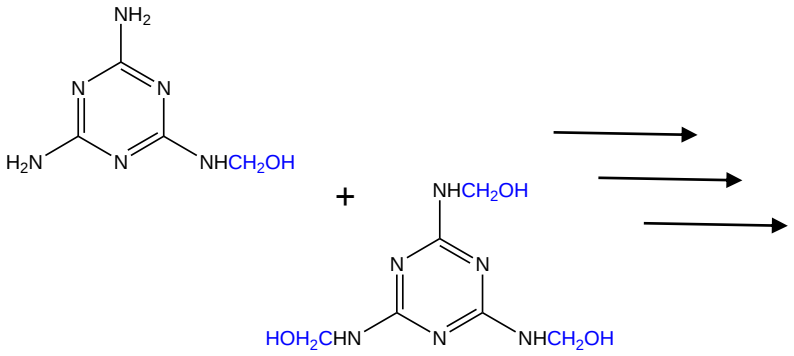


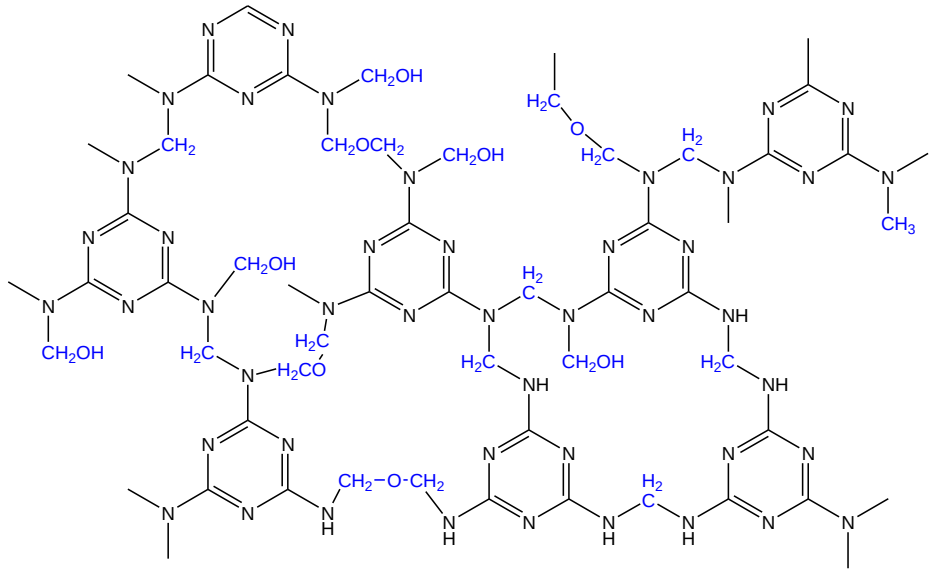
melamine *formaldehyde*



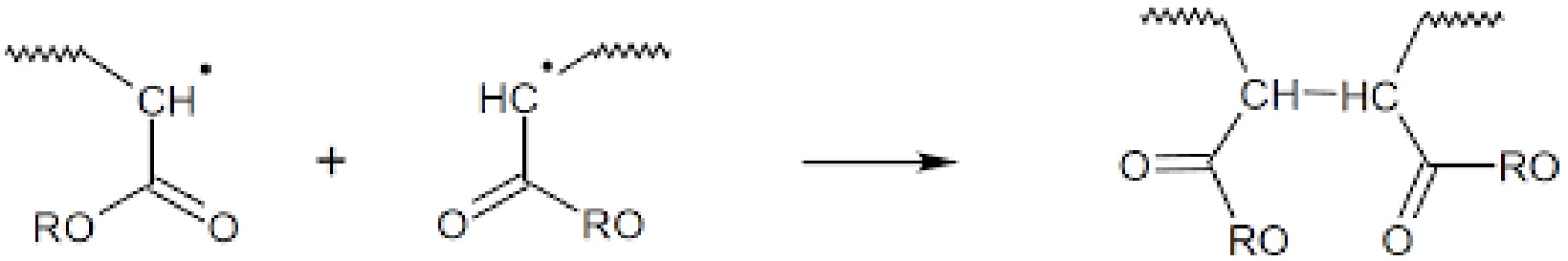
mono-, di-, and trimethylolmelamine

Condensation



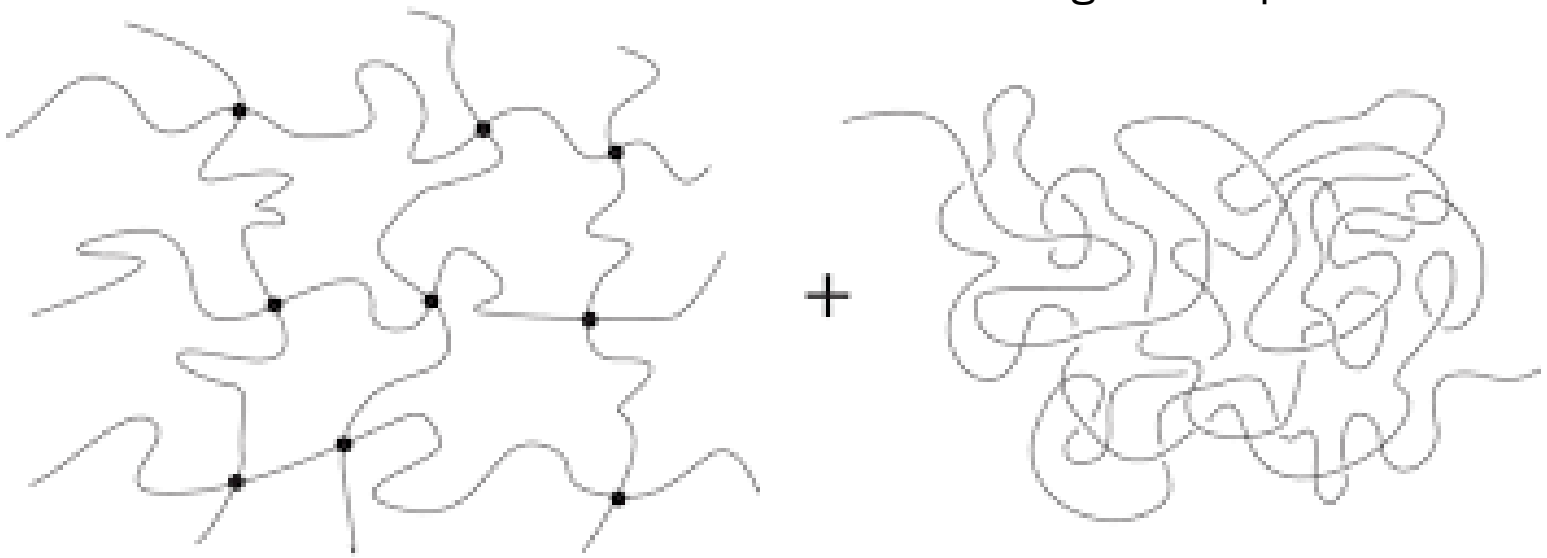


POLYACRYLATE CAPSULES

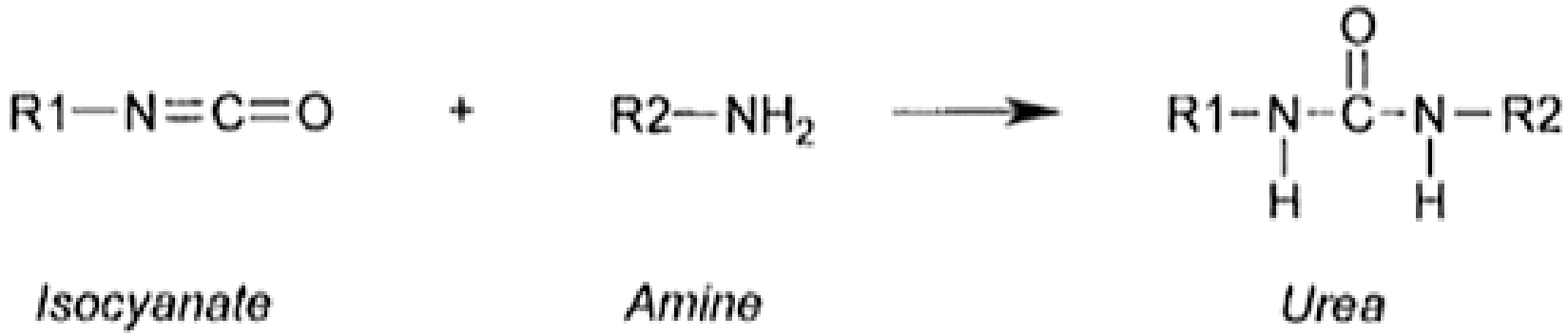


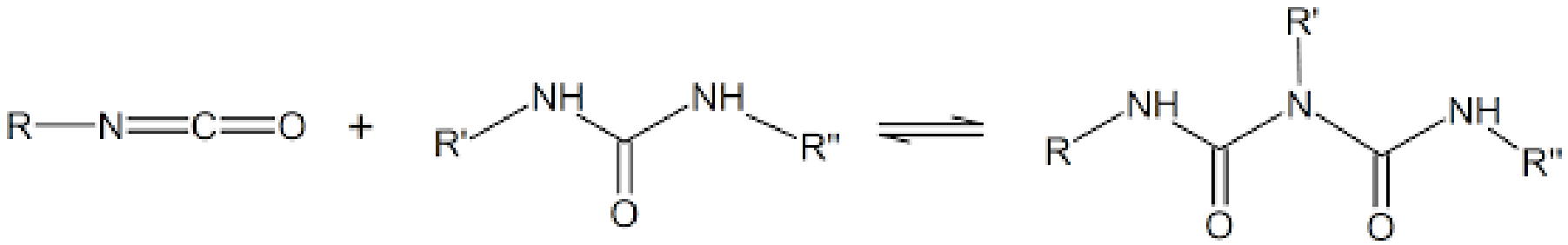
Crosslinked Component

Entangled Component



POLYUREA CAPSULES VIA ISOCYANATES





Issues with the 3 “conventional” architectures:

1) Hydrophobic
2) Little to no penetration of water
3) Biofilm establishment difficult

CAUSES OF POOR BIODEGRADABILITY

Architecture	7 Day BOD OECD 301D	14 day BOD OECD 301D	21 Day BOD OECD 301D	28 Day BOD OECD 301D
Melamine-Formaldehyde	12%	18%	24%	20%
Polyisocyanate-Amine	7%	11%	17%	20%
Polyacrylate	4%	3%	3%	3%

Poor biodegradability of these membranes could be a result of:

1) Highly crosslinked membranes
2) Poor ability for microbes to form biofilms around the material
3) Toxic by-products of degradation??
4) Lack of enzymes that can break down the membrane into smaller units

POTENTIAL APPROACHES

- Use conventional capsule technology approaches (i.e. polycondensation, free radical polymerization, or interfacial polymerization acid-base reaction chemistry)
- Introduce synthetic new materials that have lots of esters in the backbone
- Introduce natural materials in the membrane
- Introduce catalysts in the oil phase and water phases to induce reactions between components that are typically inert/non-reactive

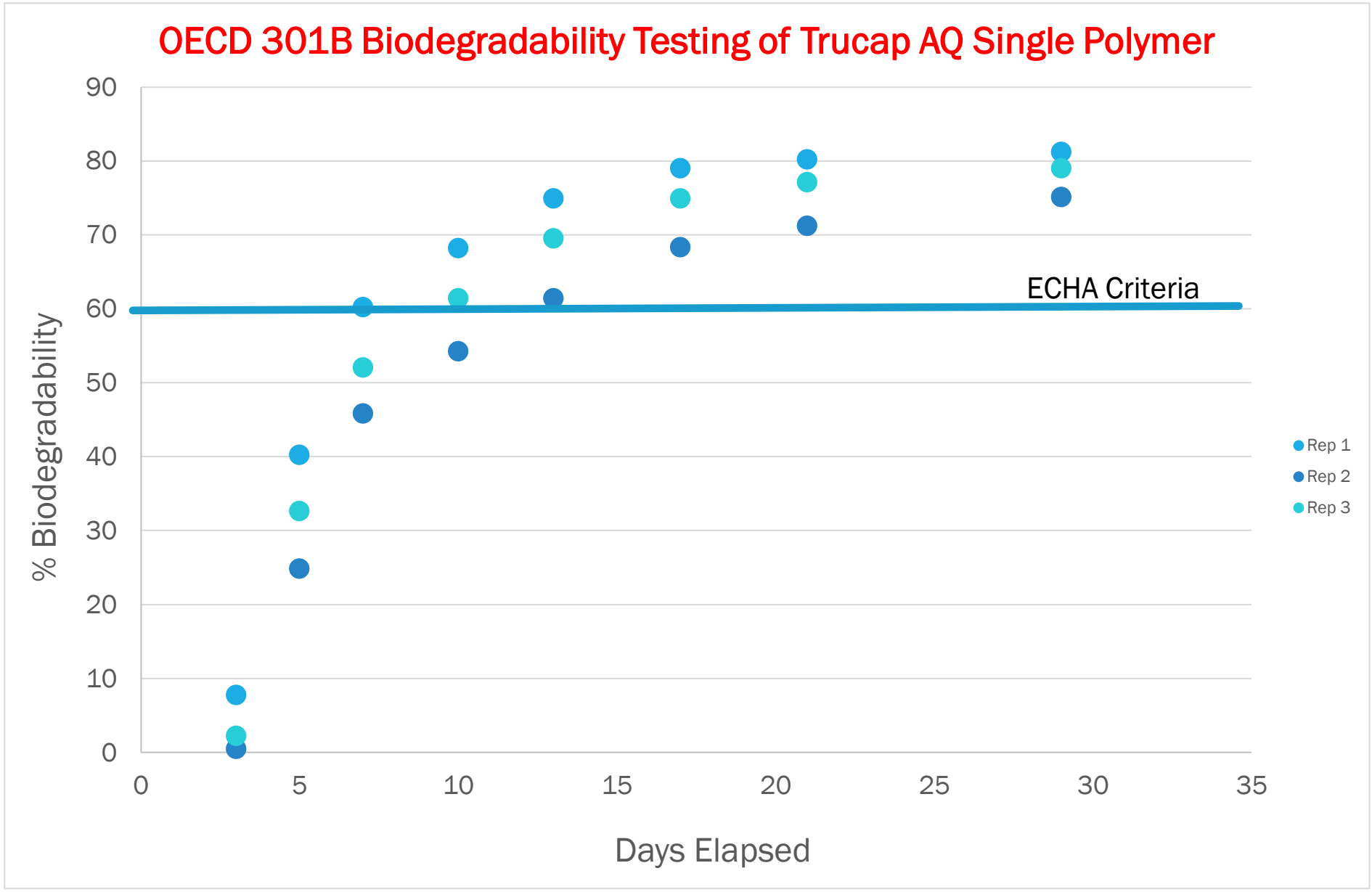
➔ **Reported biodegradability is generally less than 40% for these approaches**

➔ **Difficult to balance crosslink density (for leakage stability and performance) vs. biodegradability**

TRUCAPSOL'S APPROACH

- Choice of materials
- Such materials must be chosen such that they can be easily broken down by extracellular enzymes released by common microorganisms
- The materials chosen should not hinder deposition of capsules onto the desired substrate
- The materials chosen should enhance the chemical stability of the capsules
- The materials chosen should not adversely affect the release of the encapsulated active

BIODEGRADABILITY – EUROFINS (MARYLAND, USA)



EXCELLENT STABILITY AND PERFORMANCE – LFE

Sample	1wk/40C Leakage in LFE	4wk/40C Leakage in LFE	Laundry Performance at 4wk/40C Pre-rub / Post-rub
Architecture BY	23%	25%	1 / 4

EXCELLENT STABILITY AND PERFORMANCE - HDL

Sample	1wk/40C Leakage in HDL	4wk/40C Leakage in HDL	Laundry Performance at 4wk/40C Pre-Rub / Post-Rub
Architecture BY	4%	8%	1 / 4

Scale

0 No odor
1 Very low odor intensity
2 Low odor intensity
3 Noticeable odor intensity
4 High odor intensity
5 Very high odor intensity

CONFIDENTIAL

ACCORD FLEXIBILITY

- We don’t see new fragrance components generated as a result of our capsule chemistry
- Our perfume oil has the following profile

Functional Group	wt%	ClogP Range	BP Range
Nitrile	3.50%	3.1 - 3.6	110-350°C
Aldehyde	31.75%	1.8 - 4.9	196 -400°C
Ester	33.60%	1.9 - 4.6	152 - 394°C
Alcohol	12.70%	1.2 - 3	190-350°C
Ketone	9.75%	3.5 - 5	267-383°C
Ether	2%	3.5	274°C
Terpene	5%	4.5	177°C
Minors	1.70%	3.0 - 5.0	300-400°C

Average ClogP = 3.84

Average Boiling Point = 281°C

- We have encapsulated over 25 different fragrance compositions and have not seen a change in hedonics.

COLLABORATION MODEL

- Define success criteria
- Define key milestones to be achieved and timing
- Identify resources needed
- Produce prototypes for testing
- Develop collaboration framework
- Consumer testing
- Scale-up

TRuCapSol LLC

Thank You!

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