université PARIS-SACLAY

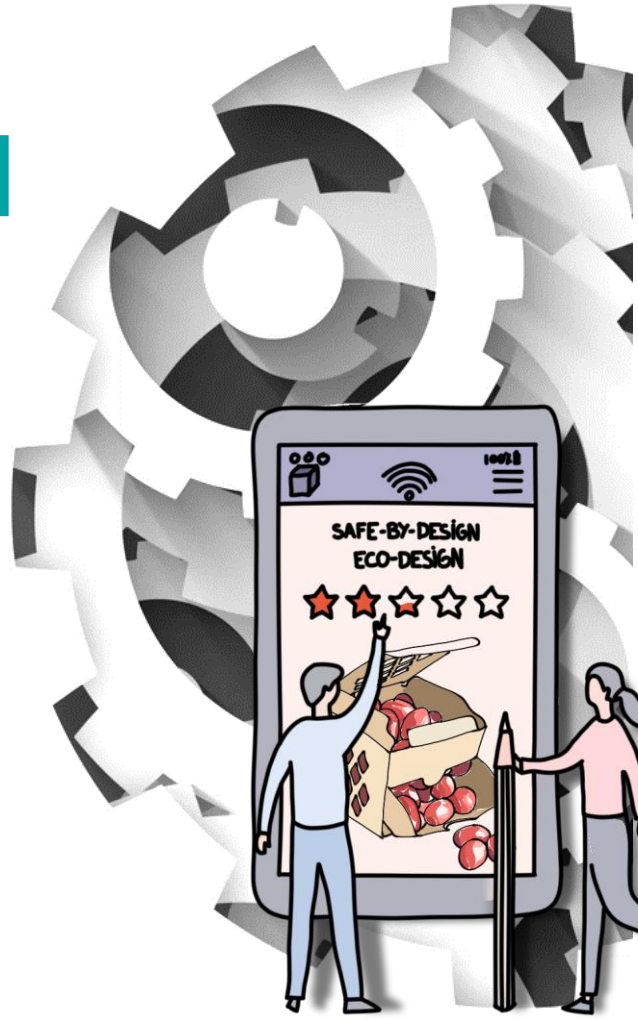
INRAE Department Food, Bioproducts and Waste

AgroParisTech
Talents for a sustainable planet

LABORATOIRE NATIONAL DE MÉTROLOGIE ET D'ESSAIS LNE

Managing the systemic risk of food contamination from packaging in the circular economy

UMR 0782 SayFood Food & Bioproduct Engineering | UMT ACTIA 22.07 SAFEMAT SAFETY OF PACKAGING



Olivier Vitrac, senior scientist at INRAE (https://www.inrae.fr/en)

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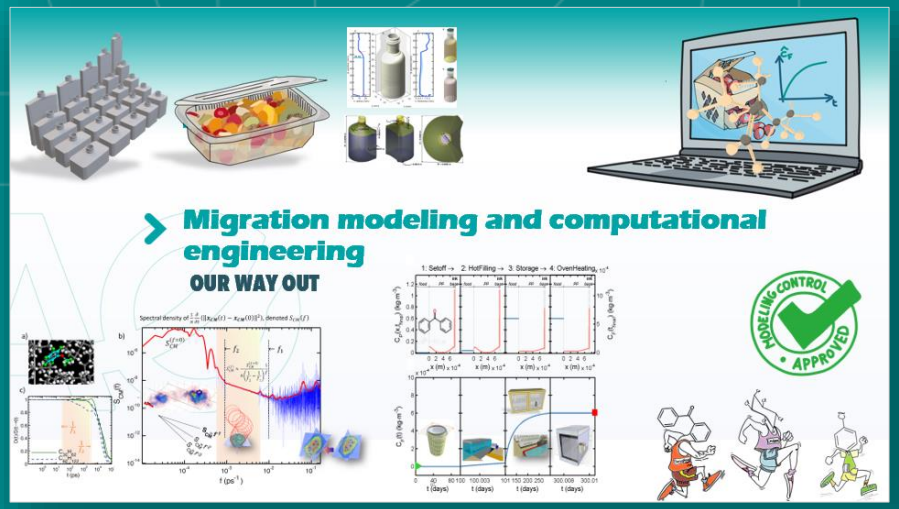
https://linkedin.com/in/olivier-vitrac-safemat
https://fitness.agroparistech.fr
orcid: 0000-0001-7787-5962

Presentation outlook

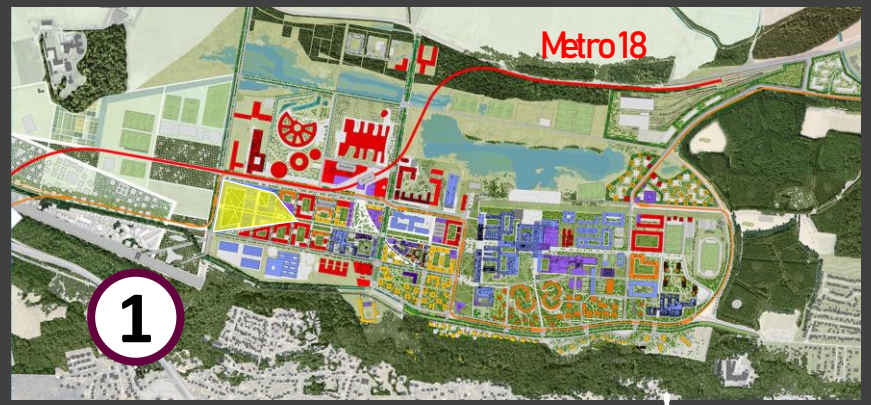


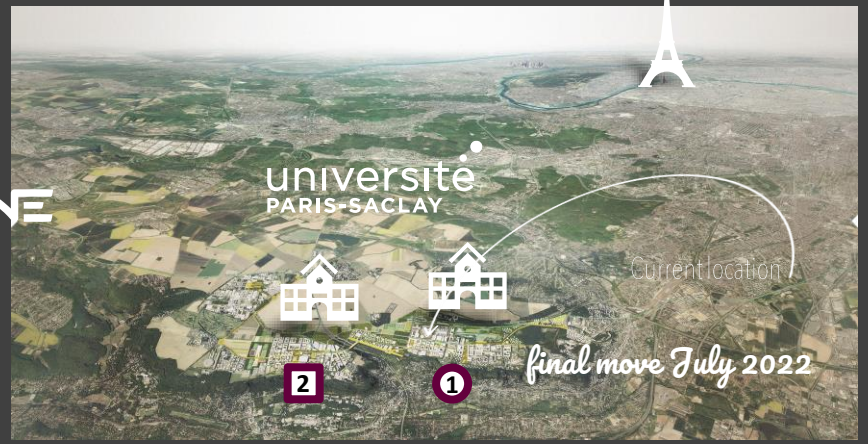
1. Who we are
2. Green Deal
3. Safety assessment
4. Computational engineering
5. Summary

INRAE AgroParisTech
Talents for a sustainable planet

UMR 0782

Joint Research Unit between INRAE and AgroParisTech – founding members of University Paris-Saclay





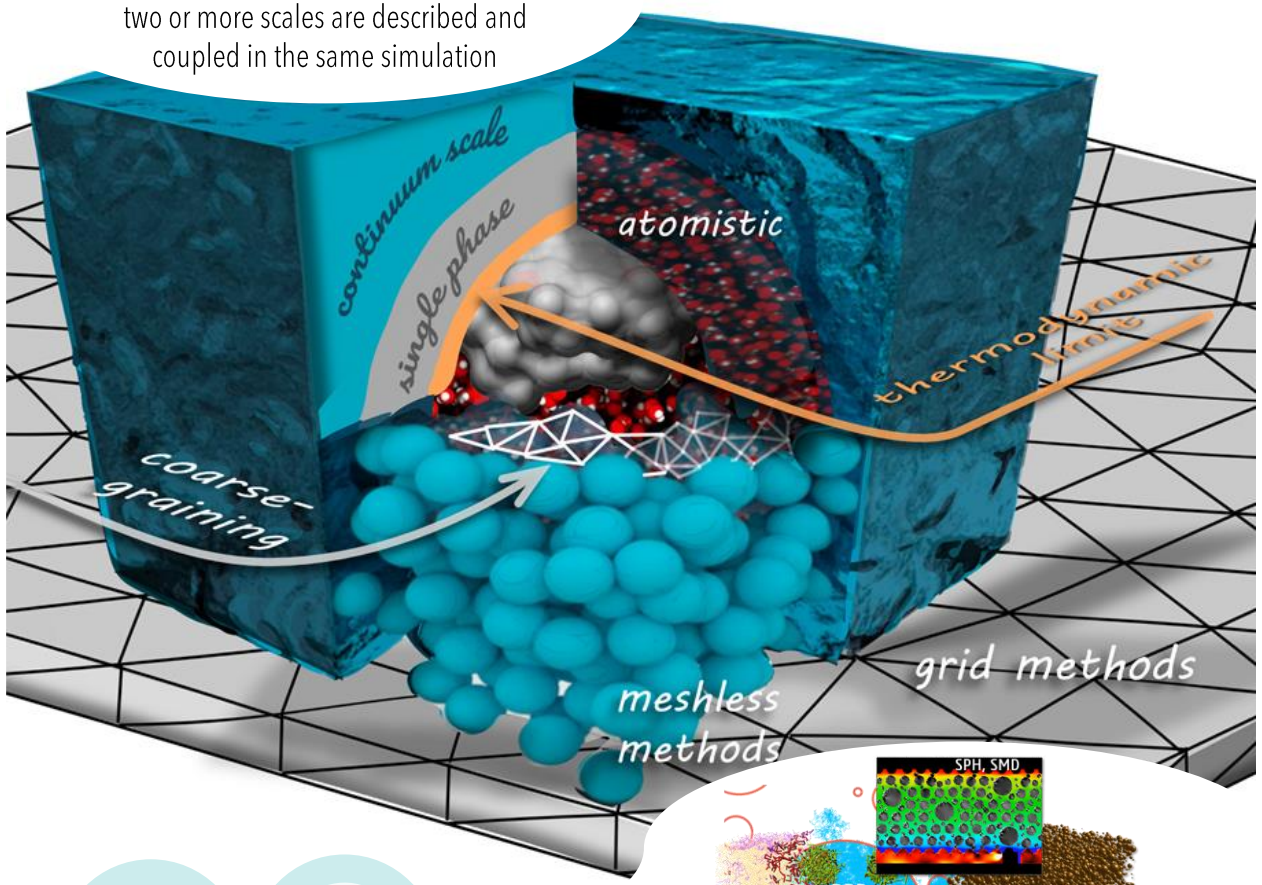
SayFood

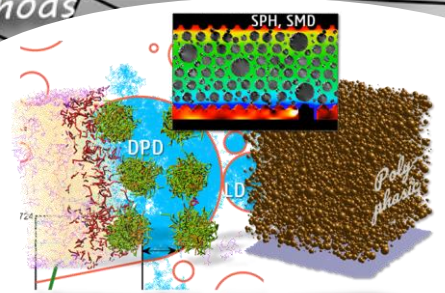
Food & Bioproduct Engineering

SayFood group modeling and computational engineering research axis: Concurrent multiscale modeling

- **Zoom in on details down to molecules within the same simulation** (food, packaging)
- Breakthrough approaches: integration of chemical and structural information, image-based modeling, chemical reactions.
- Public-private partnership

two or more scales are described and coupled in the same simulation





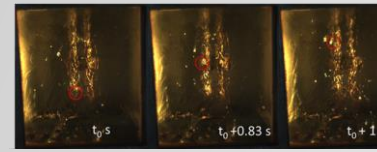
SayFood
Food & Bioproduct Engineering

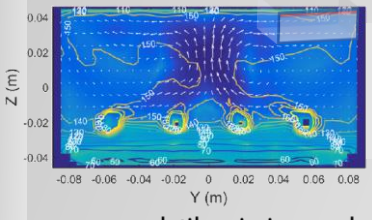
HPC

open source

Illustrations application to deep-frying

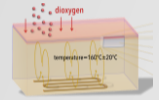
Work with Cargill

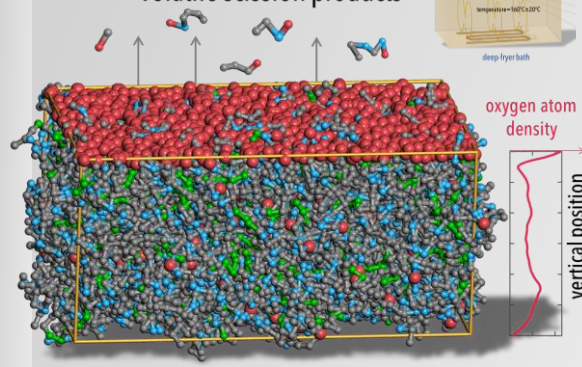




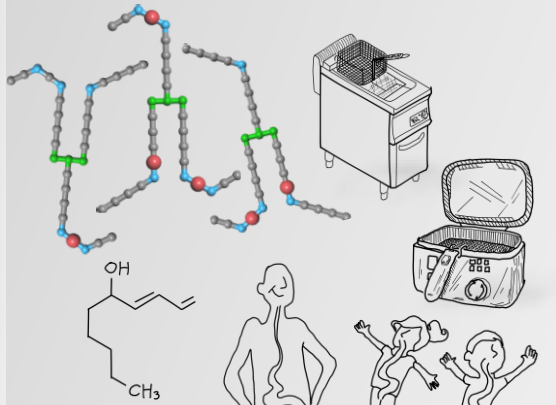
Physics of fluids **2021**. 33: 085105 .

volatile scission products





elementary volume at the extreme surface



Safemat project built around 3 R&D axes (TRL 1-7)

AXIS 1
FOOD GRADE
RECYCLATES

AXIS 2
AGING OF
RECYCLED MATERIALS,
REUSED, REEMPLOYED,
COMPOSTABLE

AXIS 3
ENGINEERING
INTEGRATING THE COUPLE
PACKAGING-PRODUCT

Mission of public interest, support the evolution of regulations, reconcile safety and performance

TOMORROW EVERYTHING SHOULD BE
REUSABLE, REFILLABLE, RECYCLABLE

TURNING GREEN

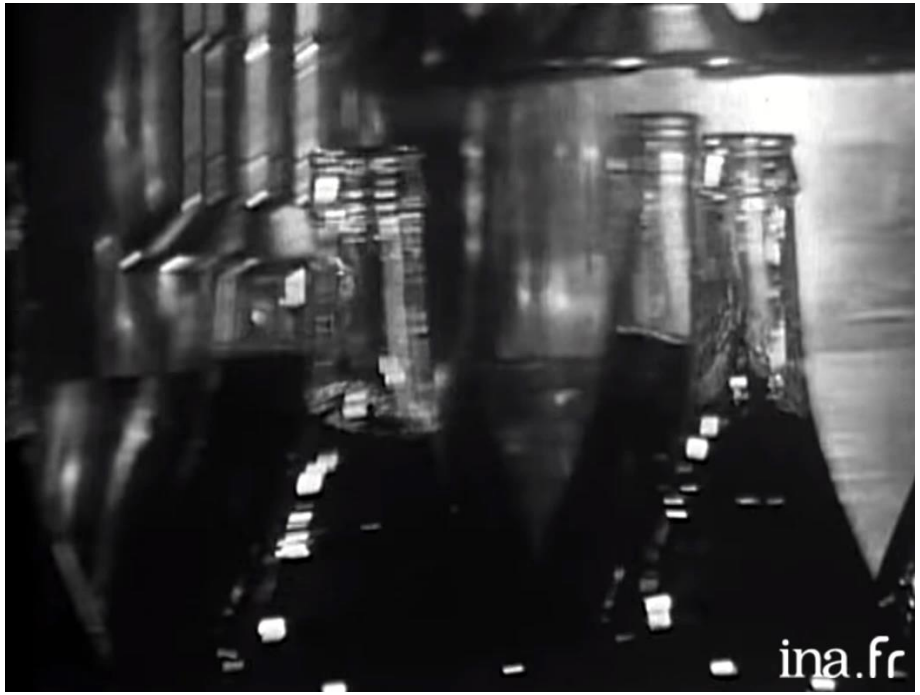
We are sleeping on a volcano... A wind of revolution blows; the storm is on the horizon.

Alexis de Tocqueville (1848, just prior revolutions in Europe).

Back to the past

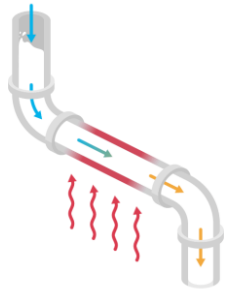
Is there a lesson we can learn from history?

1964 – first PVC bottles

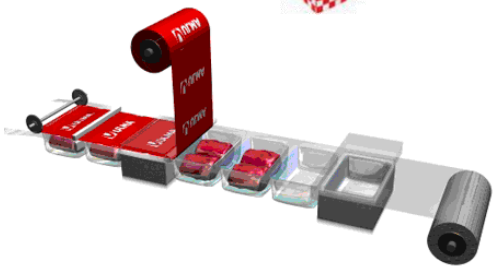


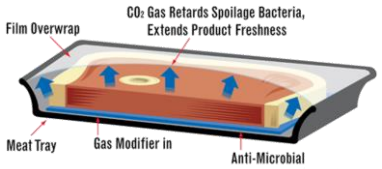
1974 – returnable bottles more expensive than plastic ones

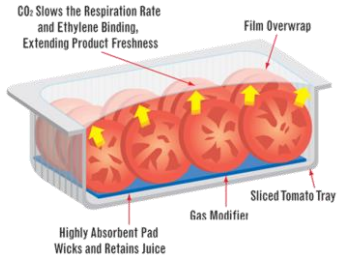
https://fitness.agroparistech.fr/fitness/external/AgroParisTech/Introduction/

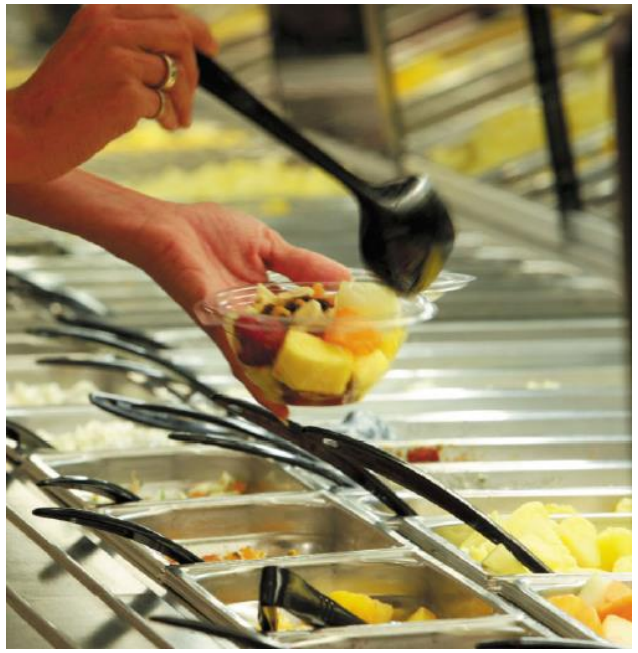


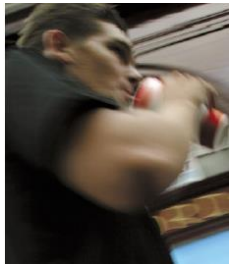
Ultra
High
Temperature









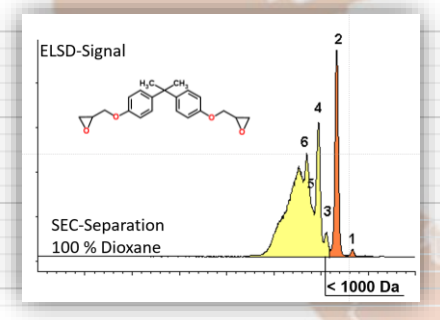


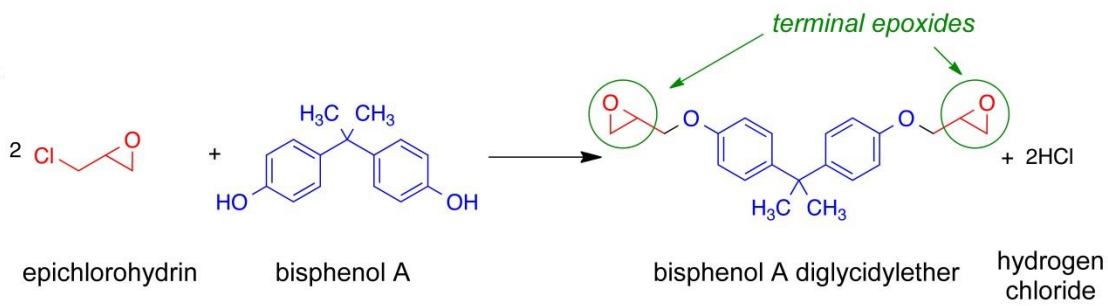

Vietnam
Naples
HE PROBLEM...
WASHING LIQUIDS
SYNTHETIC CLOTHES
1990
Film Overwrap
MICRO PLASTICS
ENTERING FOOD CH
ANIMAL H
HEALTH PROBLEMS CAUSED TO ANIMALS AND HUMANS
1950
Gas Retards Spoilage Bacteria, Extends Product Freshness
POLLUTED BY SINGLE-USE PLASTIC

Google Trends / Bisphenol A: (Worldwide)

#	M +1	Substances (originated from the resin)
1	359	BADGE·H_2O
2	341	BADGE
3	643	BADGE(n=1)·H_2O
4	569	Cyclo-DiBADGE
5	625	BADGE(n=1)
6	927	BADGE(n=2)·H_2O
7	491	BADGE·tBuPh*
8	909	BADGE(n=2)
9	775	BADGE(n=1)·tBuPh
10	641	BADGE·2tBuPh
11	477	BADGE·H2O·BuEtOH**
12	403	BADGE·EG*** (+)
13	459	BADGE·BuEtOH
14	509	BADGE·H2O·tBuPh
15	577	BADGE·2BuEtOH
16	687	BADGE(n=1)·EG (+)
18	743	BADGE(n=1)·BuEtOH
19	609	BADGE·BuEtOH·tBuPh
20	971	BADGE(n=2)·EG (+)

* tBuPh tert.-Butylphenol (chain stopper)
** BuEtOH Butoxyethanol
*** EG Ethyleneglycol
(+) Further confirmations are necessary





CANCO: Ensuring the safety of consumers: can **coatings** for direct food contact. Project QLAM-2001-00066.

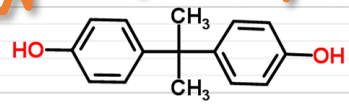
Current Biology 2003, 13, 546

Current Biology 2018, 28,1

RÉPUBLIQUE FRANÇAISE
JOURNAL OFFICIEL
LOIS ET DÉCRETS
Mercredi 26 décembre 2012 / N° 300

LOI no 2012-1442 du 24 décembre 2012

REGULATION 2018/213/EC



2003

2005-09 2006-01 2006-05 2006-09 2007-01 2007-05 2007-09 2008-01 2008-05 2008-09 2009-01 2009-05 2009-09 2010-01 2010-05 2010-09 2011-01 2011-05 2011-09 2012-01 2012-05 2012-09 2013-01 2013-05 2013-09 2014-01 2014-05 2014-09 2015-01 2015-05 2015-09 2016-01 2018-09

2018

Current Biology, Vol. 13, 546–553, April 1, 2003, ©2003 Elsevier Science Ltd. All rights reserved. DOI 10.1016/S0960-9822(03)00189-1

Bisphenol A Exposure Causes Meiotic Aneuploidy in the Female Mouse

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Arlene Ilagan,[1] Robert C. Voigt,[2,5] Sally Thomas,[3]
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Summary

Background: There is increasing concern that exposure to man-made substances that mimic endogenous hormones may adversely affect mammalian reproduction. Although a variety of reproductive complications have been ascribed to compounds with androgenic or estrogenic properties, little attention has been directed at the potential consequences of such exposures to the genetic quality of the gamete.

Results: A sudden, spontaneous increase in meiotic disturbances, including aneuploidy, in studies of oocytes from control female mice in our laboratory coincided with the accidental exposu… environmental source of bisphe… estrogenic compound widely us… polycarbonate plastics and epo… damaged caging material as the … as we were able to recapitulate … ties by intentionally damaging c… In subsequent studies of female … daily oral doses of BPA to direc… that low levels of BPA disrupt female meiosis. Our results demonstrated that the meiotic effects were dose dependent and could be induced by environmentally relevant doses of BPA.

Conclusions: Both the initial inadvertent exposure and subsequent experimental studies suggest that BPA is a potent meiotic aneugen. Specifically, in the female mouse, short-term, low-dose exposure during the final stages of oocyte growth is sufficient to elicit detectable meiotic effects. These results provide the first unequivocal link between mammalian meiotic aneuploidy and an accidental environmental exposure and suggest that the oocyte and its meiotic spindle will provide a sensitive assay system for the study of reproductive toxins.

Introduction

An estimated 10%–25% of fertilized human oocytes are aneuploid; thus, numerical chromosome abnormalities are the leading cause of miscarriage, congenital defects, and mental retardation [1]. Because almost all such aneuploidy derives from meiotic errors, considerable effort has been directed at identifying factors that increase meiotic nondisjunction. A number of potential risk factors, including irradiation (e.g., [2, 3]), smoking or drinking (e.g., [4, 5]), oral contraceptives and fertility drugs (e.g., [4, 6]), and environmental pollutants/pesticides (e.g., [7]), have been suggested. However, significant effects have been small and difficult to verify or disputed, making positive associations hard to establish. In part, this may reflect difficulties in detection. For example, the extraordinary effect of maternal age on aneuploidy may obscure less obvious associations. Further, previous studies may have focused on the "wrong" population; that is, most utilized liveborns, although virtually all aneuploidy terminates in miscarriage. Thus, the contribution of environmental insults to meiotic chromosome errors remains unknown.

We recently experienced an inadvertent environmental exposure in our mouse colony to 2,2-(4,4-dihydroxydiphenol)propane, or bisphenol A. Bisphenol A (BPA) is the monomer that is polymerized to manufacture polycarbonate plastic products and resins, such as those used to line cans containing food and beverages and those found in dental sealents. The exposure was accompanied by highly significant increases in meiotic …abnormalities, including nondisjunction; …l A was implicated as a potent disruptor …e ability to experimentally recreate the …llowed us to verify our initial observations …lose-response studies.

A Sudden Increase in Meiotic Abnormalities Is Correlated with Damage to Caging Materials

We recently reported meiotic studies of mouse mutants with defects in the alignment of the chromosomes on the first meiotic (MI) spindle [8]. This meiotic abnormality, which we have termed congression failure (Figure 1), is of particular relevance to humans because it is an age-related feature of human oocytes and has been postulated to be causally related to the well-known increase in aneuploidy associated with advancing maternal age [9].

In the course of meiotic studies of mouse oocytes conducted in 1998, we observed a sudden and dramatic change in congression failure levels. The first wave of follicles that initiate growth in the sexually immature ovary provides access to a large cohort of oocytes, and, typically, only 1%–2% of oocytes from control females exhibit congression failure at metaphase I [8]. However, in experiments conducted in August 1998, congression failure levels suddenly spiked, and approximately 40% of control oocytes exhibited this phenotype or more severe aberrations (Figures 1 and 2).

At the same time that these studies were being conducted, we were also using the animal facility to house

*Correspondence: pah13@po.cwru.edu
[5]Present address: Lab Products, 742 Sussex Avenue, P.O. Box 639, Seaford, Delaware 19973.

2003

Current Biology
Report
CellPress

Replacement Bisphenols Adversely Affect Mouse Gametogenesis with Consequences for Subsequent Generations

Tegan S. Horan,[1] Hannah Pulcastro,[1] Crystal Lawson,[1] Roy Gerona,[2] Spencer Martin,[2] Mary C. Gieske,[1] Caroline V. Sartain,[1] and Patricia A. Hunt[1,3,*]
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https://doi.org/10.1016/j.cub.2018.06.070

SUMMARY

20 years ago, accidental bisphenol A (BPA) exposure caused a sudden increase in chromosomally abnormal eggs from our control mice [1]. Subsequent rodent studies demonstrated developmental effects of exposure with repercussions on adult health and fertility (e.g., [2–9]; reviewed in [10–17]). Studies in monkeys, humans, fish, and worms suggest BPA effects extend across species (e.g., [18–30]; reviewed in [31–33]). Widespread use has resulted in ubiquitous enviro… and human BPA exposure. …sulted in "BPA-free" produc… turally similar bisphenols t… environmental and huma… [34–41]). We report here stu… changes mirroring our pre… and implicating exposure t… replacement) from damaged polysulfone cages. Like with BPA [1, 2, 5], our data show that exposure

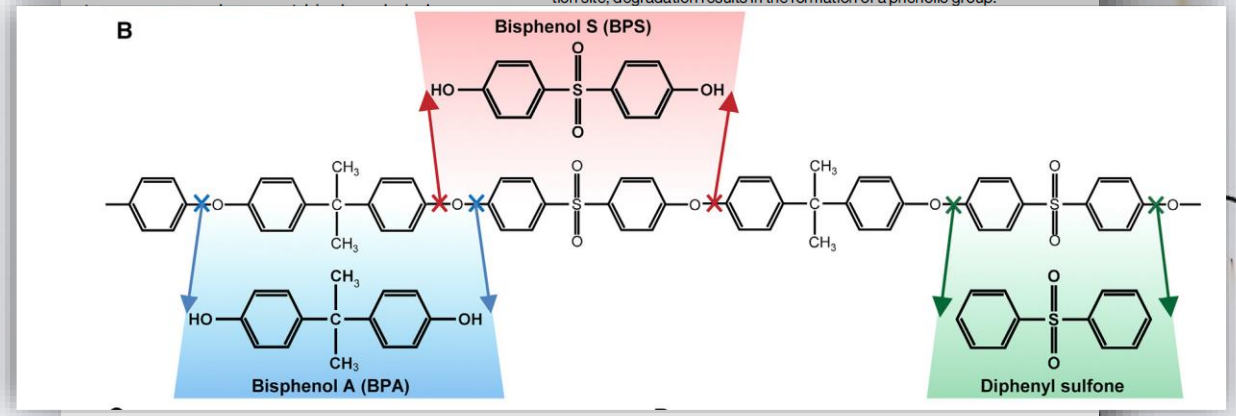
2018

Results and Discussion

In the course of meiotic studies in male and female mice, we observed variation in meiotic recombination (measured by the number of MLH1 foci in pachytene stage meiocytes), with levels in some controls reaching values characteristic of BPA-exposed animals [2, 5]. Although the change in pooled data was subtle, variation among litters was striking (Figure 1). Given our previous experience with BPA leaching from polycarbonate cages and water bottles [1], damaged materials were an obvious suspect. When white residue was evident on the surface of some polysulfone cages in our facility (Figure 2A), we suspected that exposure to chemicals leaching from the damaged polymer was eliciting …ts.

…ted Contaminant

…s comprised of BPA and diphenyl sulfone (Fig… , we suspected that these were the contaminants …iquid chromatography-tandem mass spectrometry … analysis of a methanol extraction of damaged ca… r, demonstrated the presence of both BPA and … 2C–2F). Because polymeric aromatic ethers, like …eric counterparts, cannot undergo nucleophilic substitution to generate an unsubstituted aromatic ring at the reaction site, degradation results in the formation of a phenolic group.



TURNING GREEN

TOMORROW EVERYTHING SHOULD BE REUSABLE, REFILLABLE, RECYCLABLE

PARIS 2024

PARIS 2050

ANTI-WASTE LAW for a circular economy (France)

2020

- Disposable cutlery, straws and swizzle sticks banned in 2021
- free plastic toys banned in 2021
- Plastic confetti banned in 2021

2021

- No cups, plates or cotton swabs allowed
- Prohibition of the mention biodegradable
- Expanded PS containers are not allowed
- Recycling bins in supermarkets

2022

- Banning packaging around fruit and vegetables in 2022
- Mandatory water fountains
- Plastic tea bags banned by 2022
- Inform on endocrine disruptors
- Cardboard and packaging to be sorted
- Promote bulk to reduce packaging

2023

- Mixed deposit for reuse and recycling
- **5%** packaging reusable

2024

- **100%** of packaging recycled by January 1, 2025
- A polluter-pays system for hygiene textiles from 2024
- Five-year ecodesign plans
- Disposable dishes in fast-food restaurants prohibited
- Environmental and societal labelling

2025

2026

- **Ban plastic containers for heating food for infants and young children.**

2027

- **10%** reusable packaging

2040

- **0%** of packaging are recycled since **zero** waste
- zero disposable plastic
- **100%** reusable packaging

TURNING GREEN

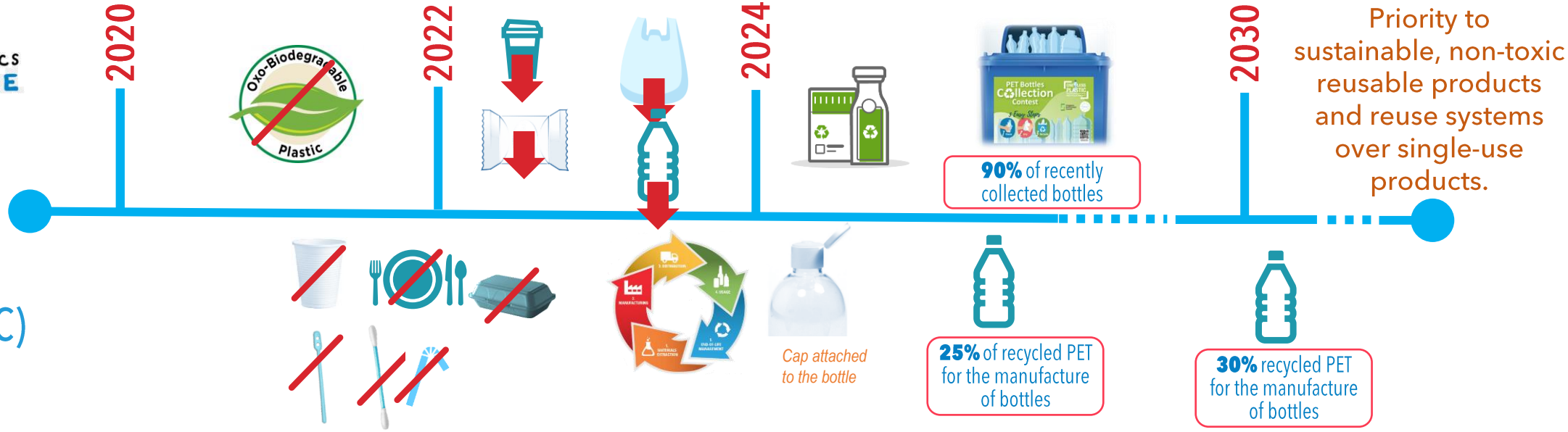
TOMORROW EVERYTHING SHOULD BE REUSABLE, REFILLABLE, RECYCLABLE

17 PARTNERSHIPS FOR THE GOALS

SUSTAINABLE DEVELOPMENT GOALS

Food Packaging impacts 12 of 17 goals

(2019/904/EC)



A world without plastics?

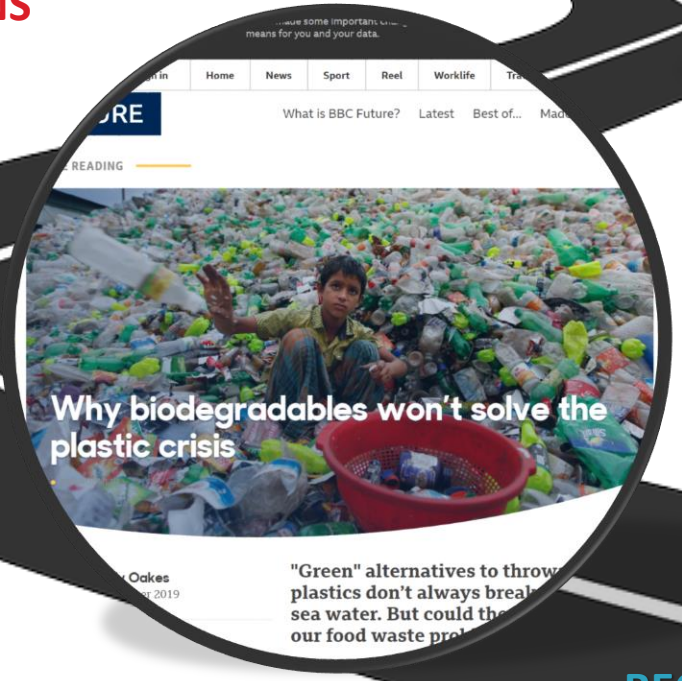
REUSED, EDIBLE PLASTICS
(new supply food supply chains)

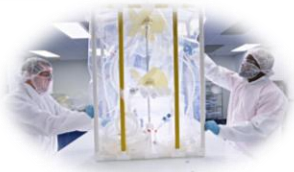
NO PLASTICS
(new organizations)

FULL COLLECT
(new usages)

ENFORCED REGULATIONS
China, EU, US

5 China Market Entry Tips... After 7 Years Analyzing Trade Policy, Legislation and Regulations

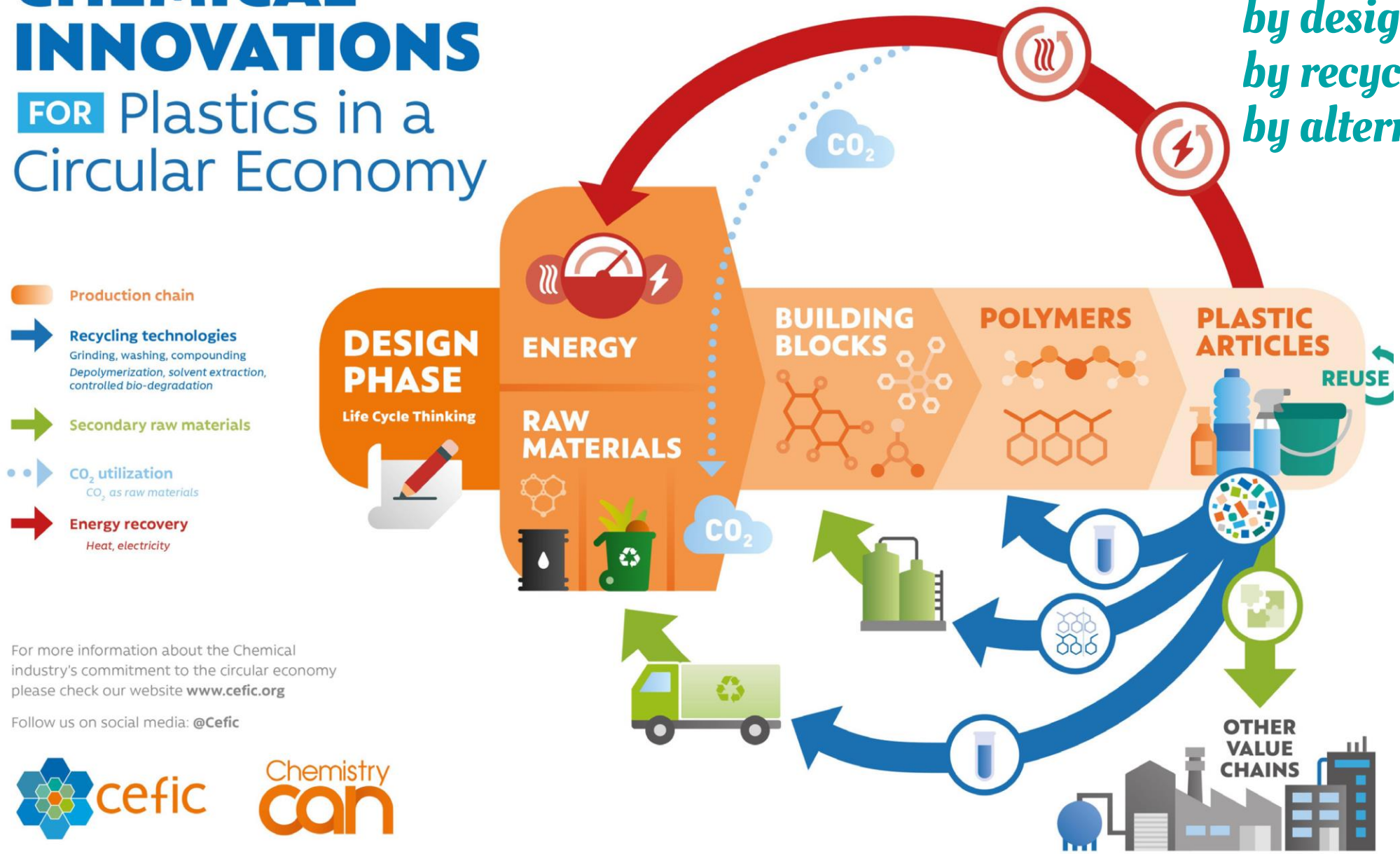




RECYCLED PLASTICS
+Food-contact

CHEMICAL INNOVATIONS FOR Plastics in a Circular Economy

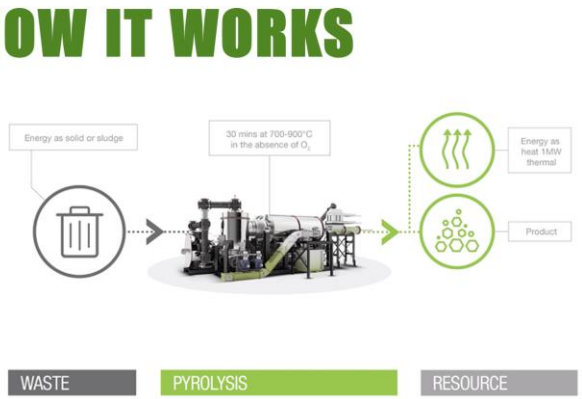
- Circularity
  - by design
  - by recycling
  - by alternative feedstocks

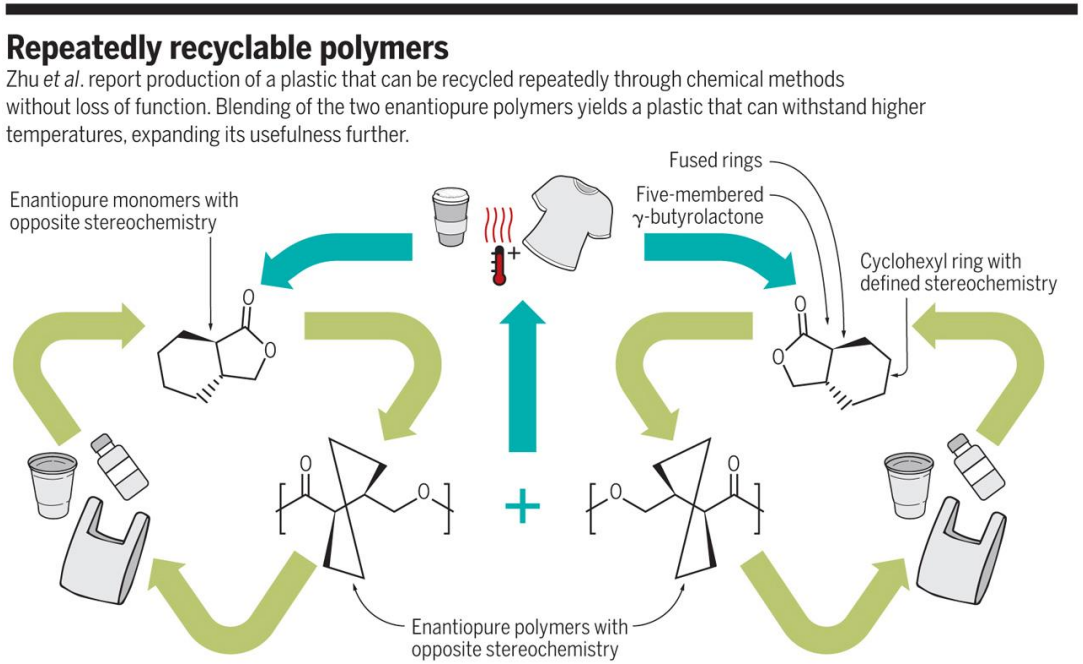


Source: Cefic

Research activities in the literature

- MATERIAL DESIGN
  - Longer lifetime
  - Decrease material usage
  - Improve sorting, separation, recyclability
  - Trigger biodegradability
- ARTICLE DESIGN
  - Design for dismantling
  - Decrease material usage
  - Digital design for reuse
  - Digital development of biobased
- RECYCLING
  - Mechanical
  - Chemical
  - Thermal and thermomechanical
  - Multimaterial, multilayer
- FEEDSTOCKS
  - Plastic waste based
  - Food waste based
  - CO/CO_2 based



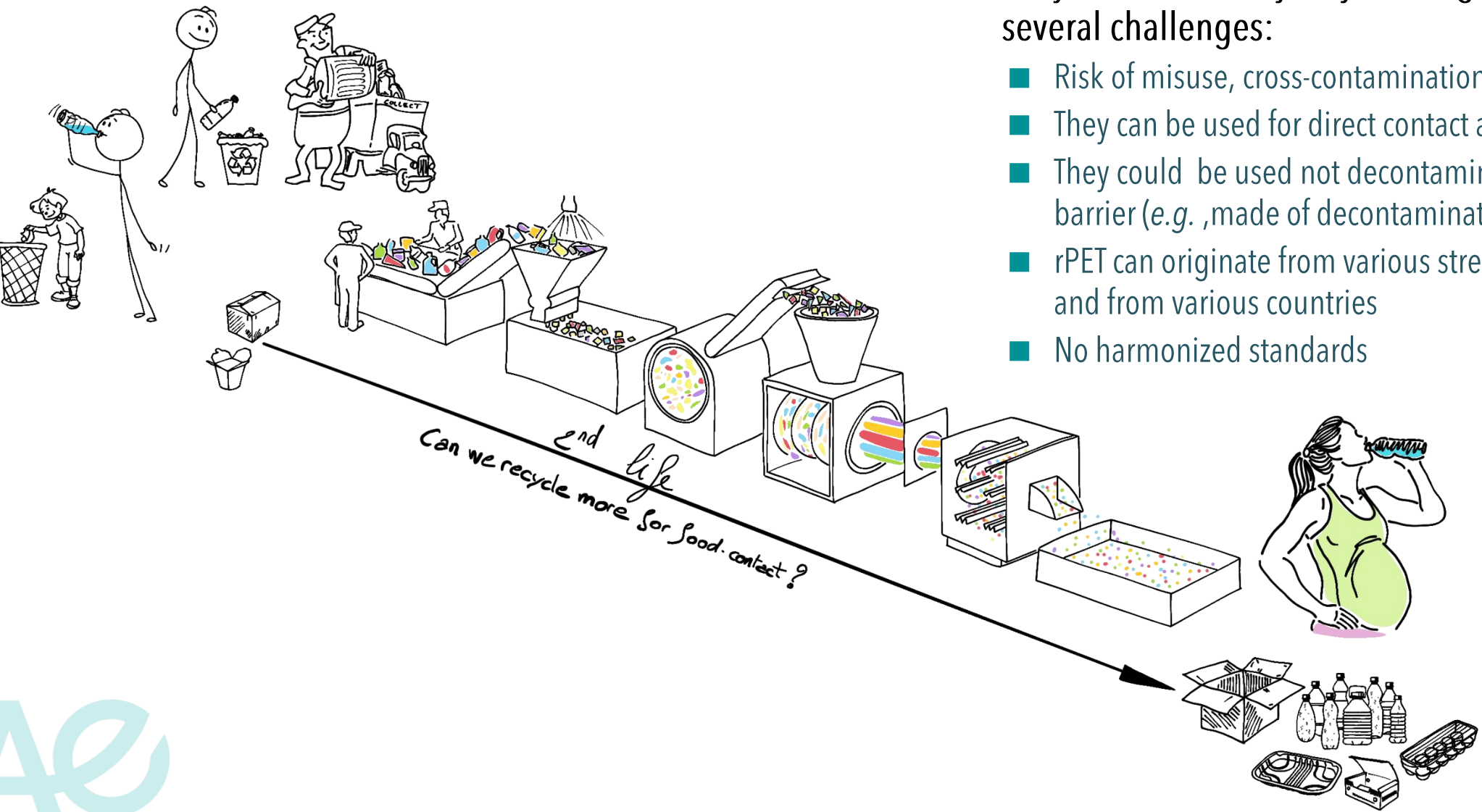


The challenge of recycling plastics for food contact.

All plastics including biosourced and biodegradable materials will need to be recyclable for the same use (food contact for food packaging).

Only PET is currently recycled at global scale, but with several challenges:

- Risk of misuse, cross-contamination (ex. from carboard)
- They can be used for direct contact after decontamination
- They could be used not decontaminated behind a functional barrier (*e.g.* ,made of decontaminated rPET)
- rPET can originate from various streams (food contact or not) and from various countries
- No harmonized standards



Recycling more plastics beyond PET

% plastic wastes in 2015
(% food packaging wastes, Plastics Europe 2016)

Globally, 18% of plastics are recycled, compared to almost zero in 1980. Plastic bottles are one of the most widely recycled products (including now to make new bottles). Other plastics are either discarded or recycled for lesser quality uses.

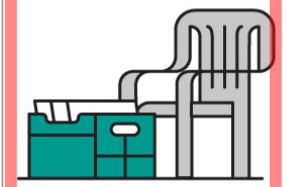
Recycling difficulties - any purpose
(variable according to regions/countries

- easy
- feasible
- dificult
- Very difficult

PET
Polyethylene terephthalate

Beverages, jars, clothing, carpets, products cosmetics...

11% (>15%)



HDPE
High density polyethylene

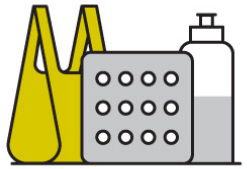
Detergents, snacks, corks, toys, barrels, garden furniture, garbage cans...

14% (~15%)

PVC
Polyvinyl chloride

Door/window frames, gutters, electric ducts, CC...

5% (<3%)



LDPE
Low density polyethylene

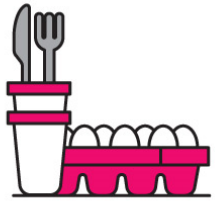
Films, bags, bubble wrap, flexible bottles, electrical insulation...

20% (32%)

PP
Propylene

Rigid closures, food boxes, coolers, tarpaulins, diapers...

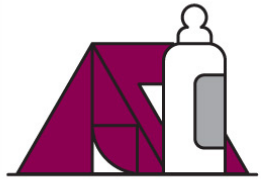
19% (~20%)



PS
Polystyrenes

Cups, egg cartons, trays, yoghurt pots, toys, electrical insulators...

6% (~10%)



Other
Plastics

Nylon/polyamide fabrics and films, CD, parts …

24% (~5%)

Recycled for food contact (PET)

Could be recycled for food contact (polyolefins: PP, HDPE, LDPE)

Recycled LDPE = a different polymer

Polymer 241 (2022) 124525

Contents lists available at ScienceDirect

Polymer

journal homepage: www.elsevier.com/locate/polymer

Computational study of the structural properties of recycled low-density polyethylene

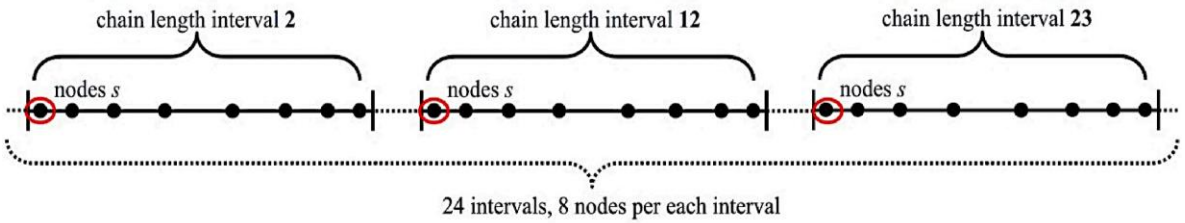
Nazila Yaghini [a,*], Remco Tuinier [a], Jaap den Doelder [a,b,**]

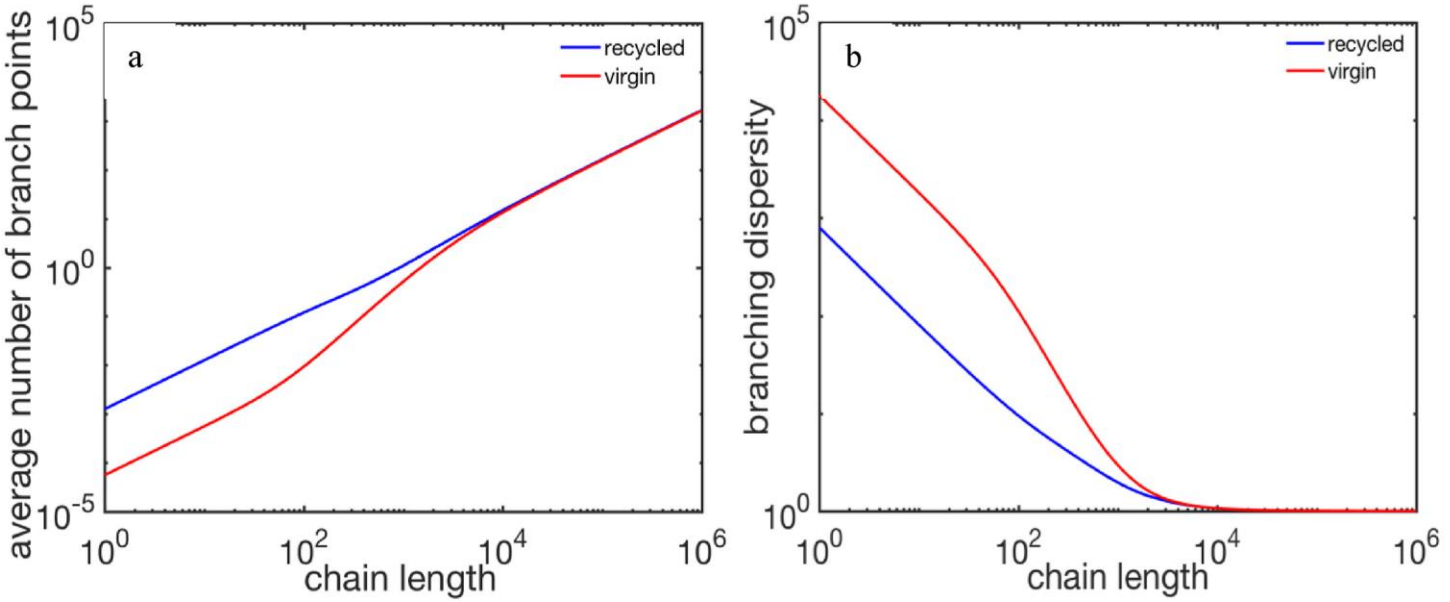
[a] Laboratory of Physical Chemistry, Department of Chemical Engineering and Chemistry & Institute for Complex Molecular Systems, Eindhoven University of Technology, P.O. Box 513, 5600, MB Eindhoven, the Netherlands

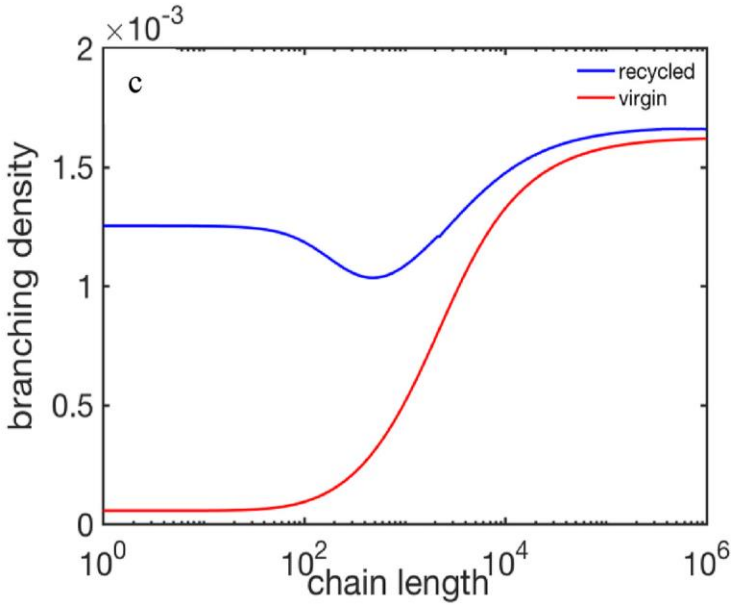
[b] Packaging and Specialty Plastics R&D, Dow Benelux BV, P.O. Box 48, 4530, AA Terneuzen, the Netherlands

ARTICLE INFO

ABSTRACT



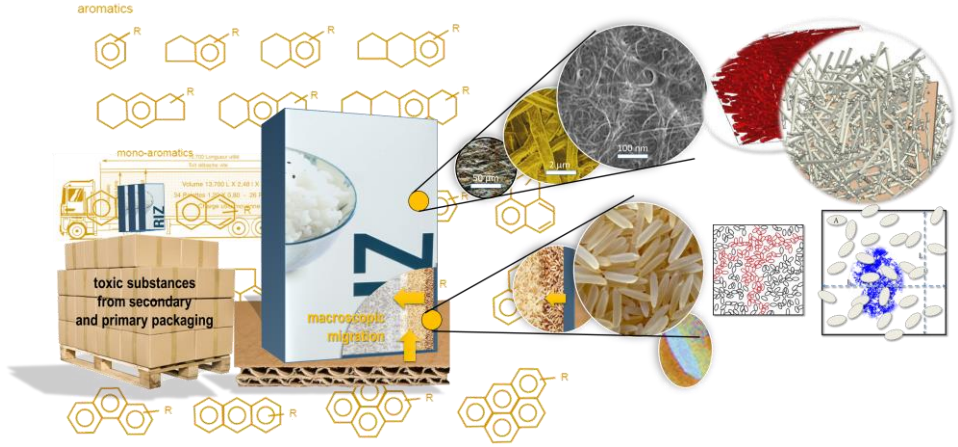




Is the substitution of plastics by recyled paper & board a safer solution?

Recycled P&B are a very important source of mineral oils, which can contaminate food without contact and across a plastic layer.

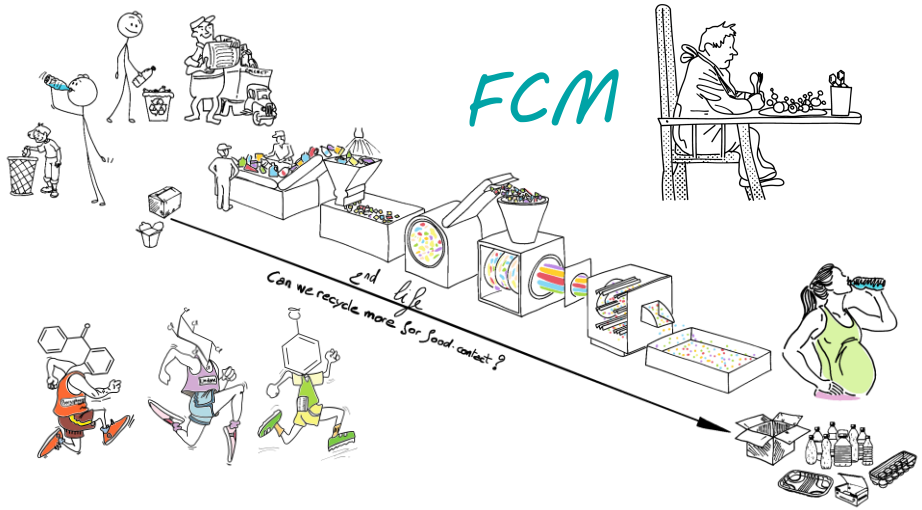
- Germany recommends not to use recycled P&B in microwave oven.
- France requires an evaluation of the risk of contamination from secondary and ternary packaging.
- Detection limit ~10 mg/kg (Koster et al., 2020)

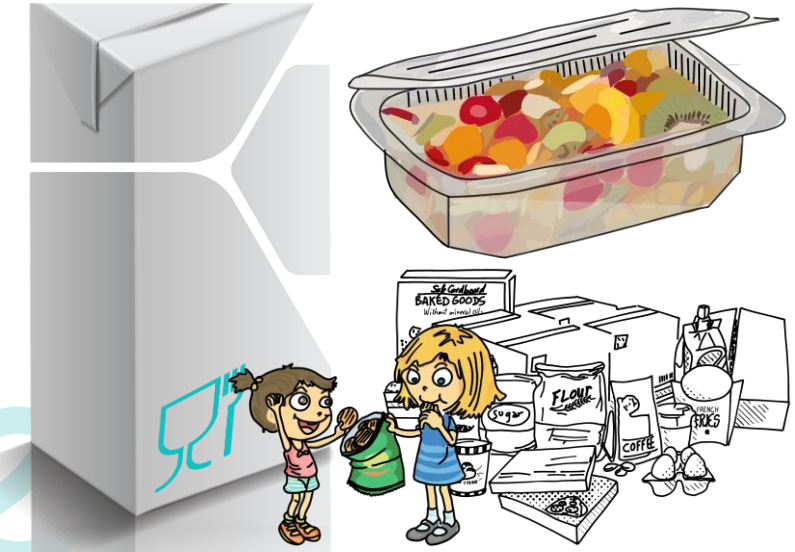


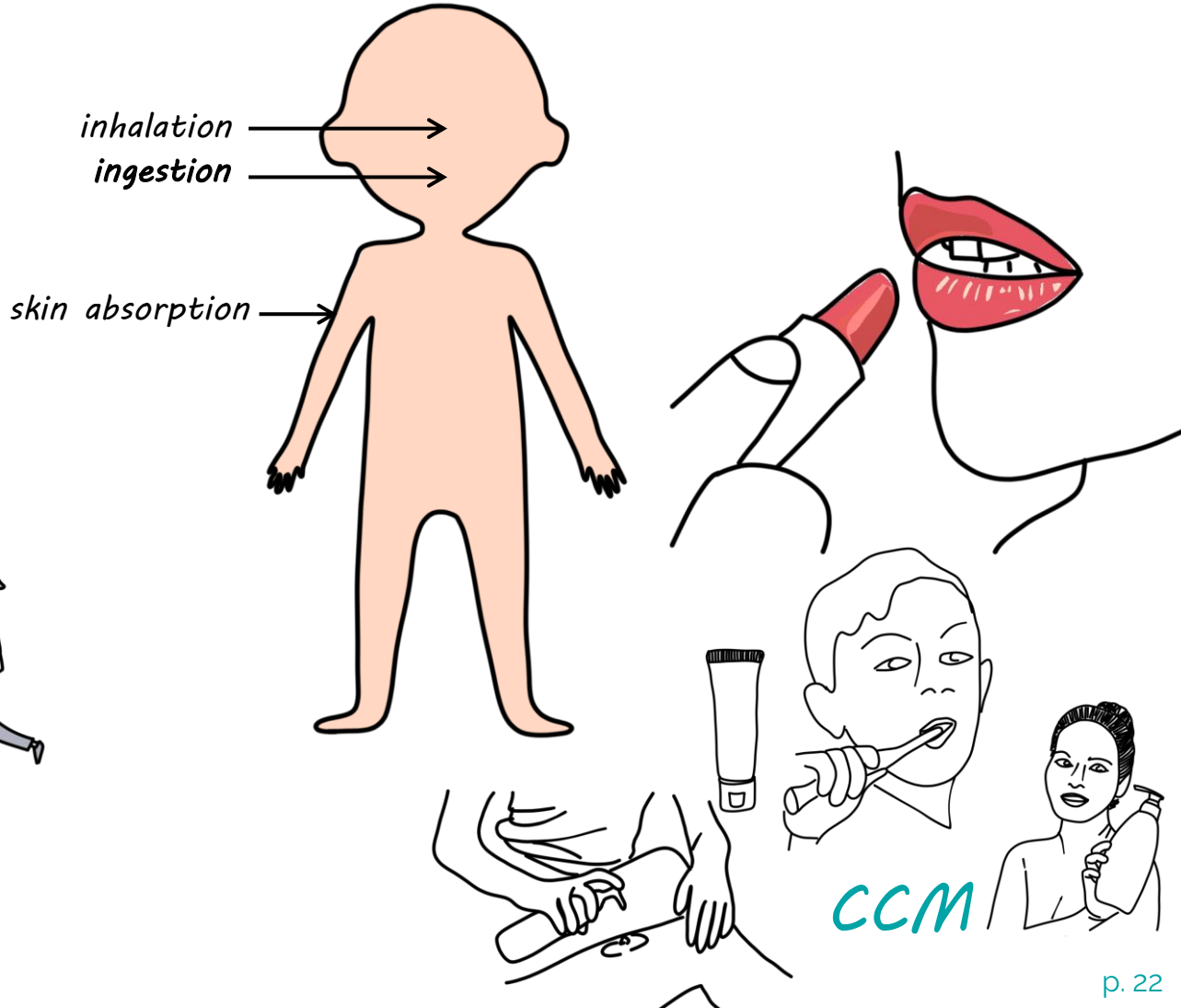
Food type	Maximum level of contamination by mineral oils	Origin	Reference
Chocolate and chocolate products	>100 mg·kg^{-1}	Cardboard	(Lorenzini, 2010)
Baby milk	10-80 mg·kg^{-1}	Cardboard	(Droz, 1997)
Cereal Products	30 mg·kg^{-1}	Cardboard and printing inks	(Biedermann, 2013)
Pasta	10 mg·kg^{-1}	cardboard box	(Biedermann, 2011)
Edible oil	100-1000 mg·kg^{-1}	Containers	(Wagner, 2001)

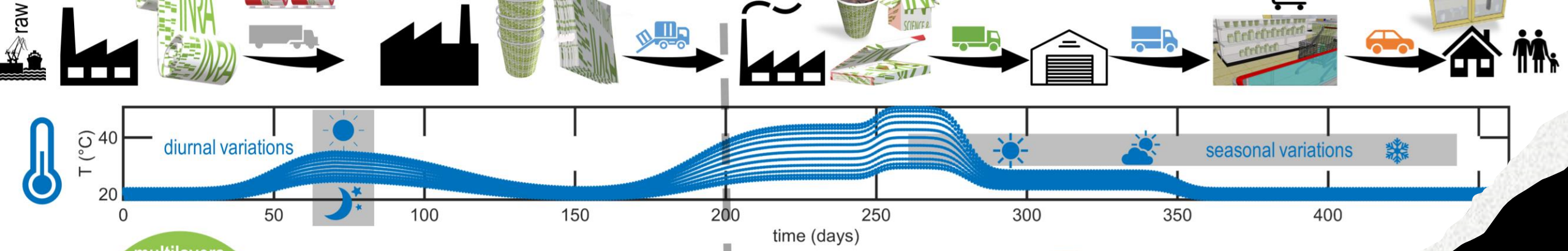
BEYOND FOOD CONTACT

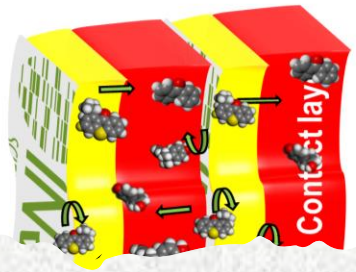
The EU regulation (EC) 1223/2009 of cosmetic products refers to the framework regulation (EC) 1935/2004 of food contact materials (FCM) to manage the risk of contamination of cosmetic contact materials (CCM)

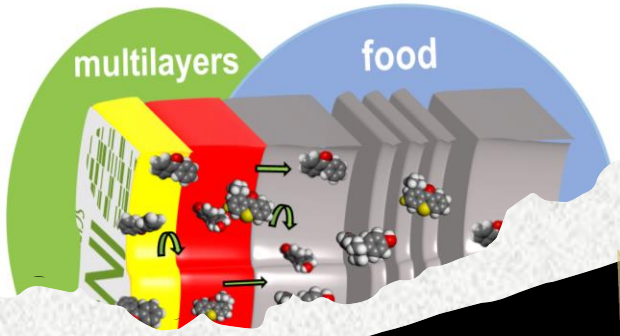






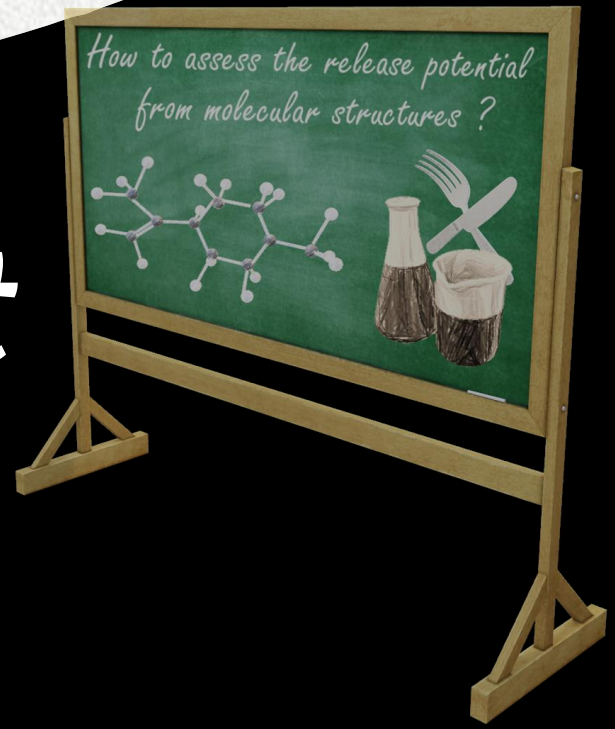


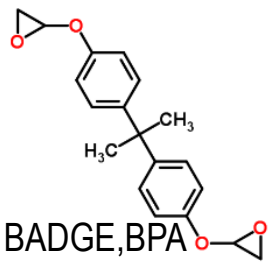


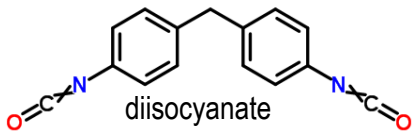


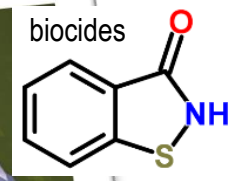
Safety Assessment

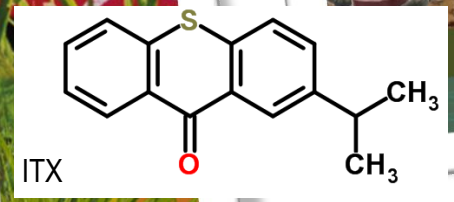
How to evaluate many new sourcing, materials, applications and practices.

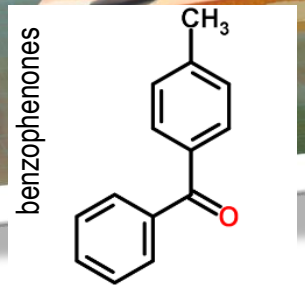


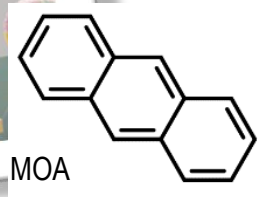

BADGE,BPA


diisocyanate


biocides


ITX


benzophenones

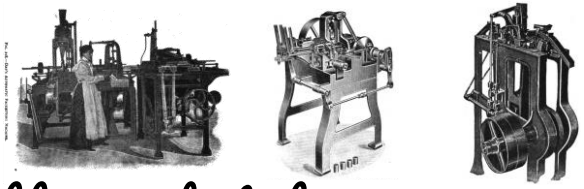

MOA

Hazard Analysis *vs* Risk assessment

Hazard = health

Risk = occurrence

Food inertia: a long history



Le règlement de 1908: « ...aucune substance alimentaire ne doit contenir de produit nuisible, produit chimiques... »

L'ART DE CONSERVER,

PENDANT PLUSIEURS ANNÉES,

TOUTES LES SUBSTANCES ANIMALES ET VÉGÉTALES;

Ouvrage soumis au Bureau consultatif des Arts et Manufactures, revêtu de son approbation, et publié sur l'invitation de S. Exc. le Ministre de l'intérieur.

Par APPERT,

Propriétaire à Massy, Département de Seine et Oise, ancien Confiseur et Distillateur, élève de la bouche de la Maison ducale de Christian IV.

« J'ai pensé que votre découverte méritait » un témoignage particulier de la bienveillance » du Gouvernement ».

Lettre de S. Exc. le Ministre de l'intérieur.

A PARIS,

Chez PATRIS et Cie Imprimeurs-Libraires, quai Napoléon, au coin de la rue de la Colombe, n° 4.

1810.

8me Année. — N° 19 — Juillet 1910

LA CONSERVE ALIMENTAIRE

Bulletin mensuel de Vulgarisation Théorique et Pratique de Fabrication

PARAISSANT LE 15 DE CHAQUE MOIS

Rédigé par un groupe de Fabricants-Industriels et de Chefs d'Emplois de cette Industrie

Nicolas APPERT
(1750-1841)

École Nationale D'INDUSTRIE ALIMENTAIRE
Nicolas Appert

COMITÉ DE DIRECTION
Bourse du Commerce
— Paris —

L'idée de la création de cette école dont nous avons été les plus fervents propagandistes vient d'être mise définitivement au point par un groupe de praticiens, de chimistes et d'agronomes distingués qui vont en assurer le fonctionnement.

L'enseignement sera tout à la fois théorique et pratique.

Dans la voie pratique, le Comité de Direction se propose, non pas d'organiser une usine de fabrication de conserves et de produits alimentaires divers, destinée à concurrencer l'industrie libre, mais de créer des laboratoires d'essais et d'enseignement que dirigera un praticien qualifié et où chaque fabricant pourra venir se documenter et concourir aux progrès de la science alimentaire

Les essais théoriques seront dirigés par un technologue éminent, M. Crolbois, chef de laboratoire à l'Institut Pasteur.

Une très large place sera réservée, dans l'enseignement à la question des machines, appareils et ustensiles employés par l'Industrie alimentaire. Un ingénieur diplômé, M. Raymond Monot, des usines de Diétrich, est chargé d'organiser cette partie du programme.

M. Moréal de Brévans, le distingué sous-directeur du laboratoire municipal, a bien voulu se charger de l'enseignement si important de la chimie appliquée à l'alimentation.

Enfin M. Ed. Jacquet, ingénieur-agronome, administrateur de l'école, occupera la chaire de professeur d'« Alimentation Commerciale ».

Ajoutons que notre bulletin transformé en revue bi-mensuelle à laquelle collaboreront désormais les personnalités ci-dessus, devient le Bulletin Officiel de l'École.

En un mot et suivant l'exemple d'autres pays, une Université nouvelle et bien moderne vient de naître en France, celle de l'Industrie Alimentaire. Cette industrie quitte ainsi, définitivement, le domaine empirique pour rentrer dans celui des sciences exactes, où elle avait

200 — LA CONSERVE ALIMENTAIRE

sa place déjà marquée par les exigences et le progrès sans cesse grandissants de la vie contemporaine.

Pour le Comité de Direction :
Aug. Corthay.

Causerie Professionnelle
par Nicolas APPERT

Méfions-nous des Conserves Étrangères

Nous donnons ci-dessous la traduction d'un extrait du passage que M. Hamel consacre à la législation et l'inspection des conserves alimentaires au Canada, dans le traité qu'il publie en ce moment. (Modern practice of canning meats) :

« Comparés avec les règlements qui régissent l'inspection des conserves alimentaires aux Etats-Unis et en Europe, ceux du Canada sont encore à l'état embryonnaire.

Pour protéger les fabricants Canadiens contre la concurrence des Etats-Unis, il était nécessaire de créer une législation, au moins sur le papier.

« Je ne parle pas ici de l'inspection des viandes fraiches qui est soumise à un groupe de savants et de vétérinaires de valeur.

« Mais l'acheteur éclairé de conserves alimentaires quelles qu'elles soient, viandes, poissons, fruits ou légumes est loin d'avoir obtenu la même sécurité.

« Le règlement en date de 1908 qui régit l'inspection des conserves alimentaires nous dit : *Aucune substance alimentaire ne doit contenir de produit nuisible, produits chimiques, colorants ou antiseptiques*, et plus loin on nous dit : *Il sera fourni aux Inspecteurs par les soins du Ministère de l'Agriculture les noms des antiseptiques et colorants inoffensifs dont l'emploi est permis. L'addition de tout autre empêchera le produit de recevoir l'étiquette constatant l'inspection.*

« Nous comprenons bien que les chimistes du Ministère sont là pour condamner tout produit alimentaire où l'analyse révélerait la présence d'un produit chimique dangereux, mais pour ceux qui sont au courant des discussions en cours entre les hygiénistes les plus distingués du monde entier au sujet de la plus ou moins grande nocivité de tel ou tel antiseptique, la satisfaction est maigre.

« Je répète que le fabricant de conserves en boîtes n'a pas besoin d'antiseptiques pour assurer la conservation indéfinie de ses produits. La stérilisation lui suffit.

« Pourquoi donc ne pas faire comprendre au monde entier que les mots « CANADA APPROVED » de l'étiquette signifient absence entière de susbstances nuisibles, aussi bien dans les conserves que dans les viandes fraiches.

« Que si quelques antiseptiques sont considérés comme inoffensifs par le Ministère de l'Agriculture, pourquoi ne pas faire connaitre au public comme aux fabricants le nom de ce qui est permis et de ce qui est prohibé?

« Le règlement de 1908 ne prend nullement en considération la qualité de la soudure employée, pas plus que celle de l'acide, et il semble que sur ce point les japonais sont bien en avance sur nous lorsqu'ils donnent les commandes pour leur armée.

« Pour en finir, il semble que des instructions plus complètes auraient été pour le plus grand intérêt du fabricant lui-même, en donnant au public consommateur une garantie parfaite de sécurité. La consommation en aurait été accrue en regagnant la confiance des consommateurs qui sont peu confiants dans les conserves, généralement sans raisons, d'ailleurs. »

G. T. Hamel, ingénieur.

L'auteur faisant une œuvre purement technique et non de polémique est évidemment très modéré. Mais pour qui lit entre les lignes et pour nous qui savons combien sont rares parmi le personnel de l'inspection les gens compétents, toutes les places étant prises par les politiciens, nous ne nous sentons pas rassu-

https://www.plasticseurope.org/application/files/2615/2933/0926/The_Role_of_Food_Packaging_2018.pdf

Inside Food Contact Materials

PlasticsEurope
FCA Food Contact Additives

WHAT YOU NEED TO KNOW

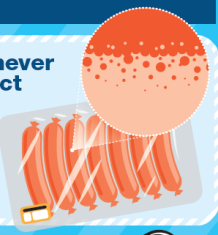
Plastic Food Contact Materials play a crucial role in preserving food from contaminants and **preventing food waste.** Yet, some worry about the chemicals that are required in the production of these important materials.

What are Food Contact Materials?

"Food Contact Materials", or FCMs for short, refers to all *materials* that come into contact with food.

Natural migration occurs whenever two materials come into contact with each other

Migration is a natural and unavoidable phenomenon that occurs **in all materials.** Whenever two materials come into contact with each other, substances can migrate from one material into another. This also happens with food packaging and food.



Risk assessments make sure that Food Contact Materials are safe

A risk assessment is based on different elements to assess potential health risks associated with exposure to substance migration into the food.

HAZARD IDENTIFICATION:
Identifies potential health effects in humans and/or environment, caused by chemicals.

EXPOSURE ASSESSMENT:
Evaluates the potential chemical exposures to humans and the environment from the production, distribution, use, disposal and recycle of a chemical substance.

RISK CHARACTERIZATION:
Integrates those identification and assessment results to determine the probability of occurrence of health and/or environmental effects in a given population.

THE RESULT ENSURES SAFE USE OF PRODUCTS

EFSA
The European Food Safety Authority performs a risk assessment of the substance to ensure a high level of human health protection. The safety limit is based on the toxicological profile of each substance.

Quantity is key

Even natural substances can interact with the body but would only cause adverse effects from a certain dose. It is the **quantity** which **sets the risk.**

Water:

Water is vital for leading a healthy lifestyle. We need water to remain hydrated and energised.

Adequate Daily Intake: around 2.5 litres[1]

Water intoxication can occur when a person drinks so much that the water dilutes the concentration of sodium in the blood, creating an electrolyte imbalance. Water intoxication, known as hyponatremia, is mostly a risk for endurance athletes.

Coffee:

Coffee has antioxidants and nutrients that contribute to good health. Coffee increases your focus and can improve energy levels.

ADI: 400 milligrams[2]

Too much caffeine can cause insomnia, restlessness, nausea, irregular heartbeat, muscle tremors, anxiety and headaches.

Soy sauce:

Soy sauce has some great health benefits: it is low in calories and very high in natural antioxidants.

ADI: 2 tablespoons (32 grams)[3]

If consumed in too large a portion, it increases blood sodium levels, potentially leading to neurological problems.

Why is packaging so important?

Food waste is a huge problem, in Europe and beyond...

16%[4] — the amount of food that the average EU consumer wastes

According to the WHO, in the less developed world up to **50%** of all food is wasted between harvest and home[4].

... and food poisoning is a massive problem as well...

351.000[5] people have globally **died** per year as a result of food poisoning.

In the UK, more than **1 million people** per year have been poisoned by deteriorated food, leading to **500 deaths**[6].

... But adequate food packaging could change this!
Packaging plays an important role in ensuring the freshness of food, extends its shelf life and helps to improve the quality of products for consumers.

In a **sustainable society**, using modern packaging and storage systems, wastage is reduced dramatically to around **3%**[4]

[1] EFSA (2009), "Dietary reference values for water": https://www.efsa.europa.eu/en/efsajournal/pub/1459
[2] EFSA, "Caffeine": http://www.efsa.europa.eu/sites/default/files/corporate_publications/files/efsaexplainscaffeine150527.pdf
[3] Calculated based on EFSA (2005), "EFSA provides advice on adverse effects of sodium": https://www.efsa.europa.eu/en/press/news/050622. 1 tbsp. (16g) of soy sauce contains 0.9g of sodium.
[4] European Commission (2015), 'Average EU consumer wastes 16% of food; most of which could be avoided': https://ec.europa.eu/jrc/en/news/average-eu-consumer-wastes-16-food-most-which-could-be-avoided?rs=dnl
[5] Time (2015), "351,000 People Die of Food Poisoning Globally Every Year": http://time.com/3786003/351000-people-die-of-food-poisoning-globally-every-year/
[6] UK government (2011), FOODBORNE DISEASE STRATEGY: https://www.food.gov.uk/sites/default/files/multimedia/pdfs/fds2015.pdf

Inside Food Contact Materials

PlasticsEurope
FCA Food Contact Additives

HOW CAN WE BE SURE THAT THEY ARE SAFE?

A SCIENCE-BASED ANALYSIS IS PERFORMED TO ENSURE THE SAFE USE OF AN ADDED SUBSTANCE

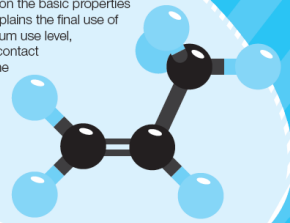
EFSA

Technical dossier

The technical dossier is part of a scientific and regulatory process which determines the safe use of an added substance

1 Identity and physico-chemical properties of the substances

The goal is to understand the substance and how it migrates. The applicant provides information on the basic properties (e.g. solubility and stability) and explains the final use of the substance, including: maximum use level, function, in which plastic(s), in contact with which foods, what are the contact conditions (time, temperature…), etc.



2 Data on the residual content of the substance in the Food Contact Material

The objective is to understand how much of the substance is present and what type of specific migration can be expected.

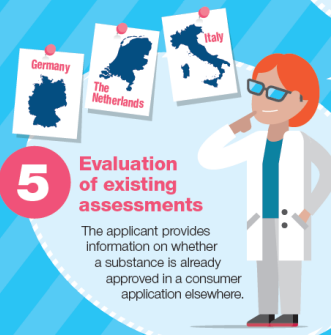
Residual content is the actual content in the final material placed on the market.

3 Migration data of the substance

The purpose is to comprehend how much of a substance is migrating into food. This is done by testing different types of food and real storage conditions (time/temperature).

4 Toxicological data and microbiological properties of the substance

The applicant needs to demonstrate that, in case of microbiological properties of a substance, these have no effect on the food. To demonstrate that levels of migration into food are safe for human consumption, the applicant provides the adequate toxicological reports.

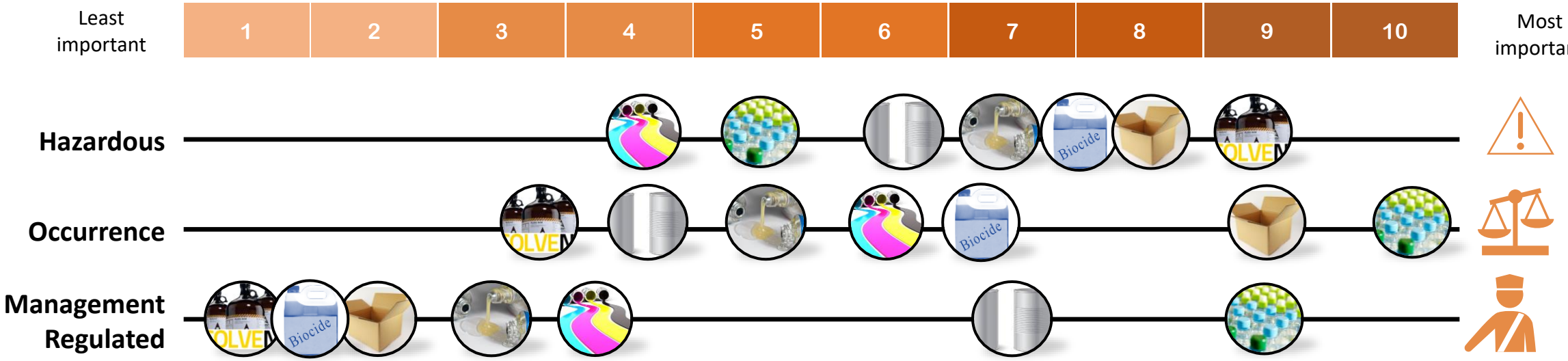


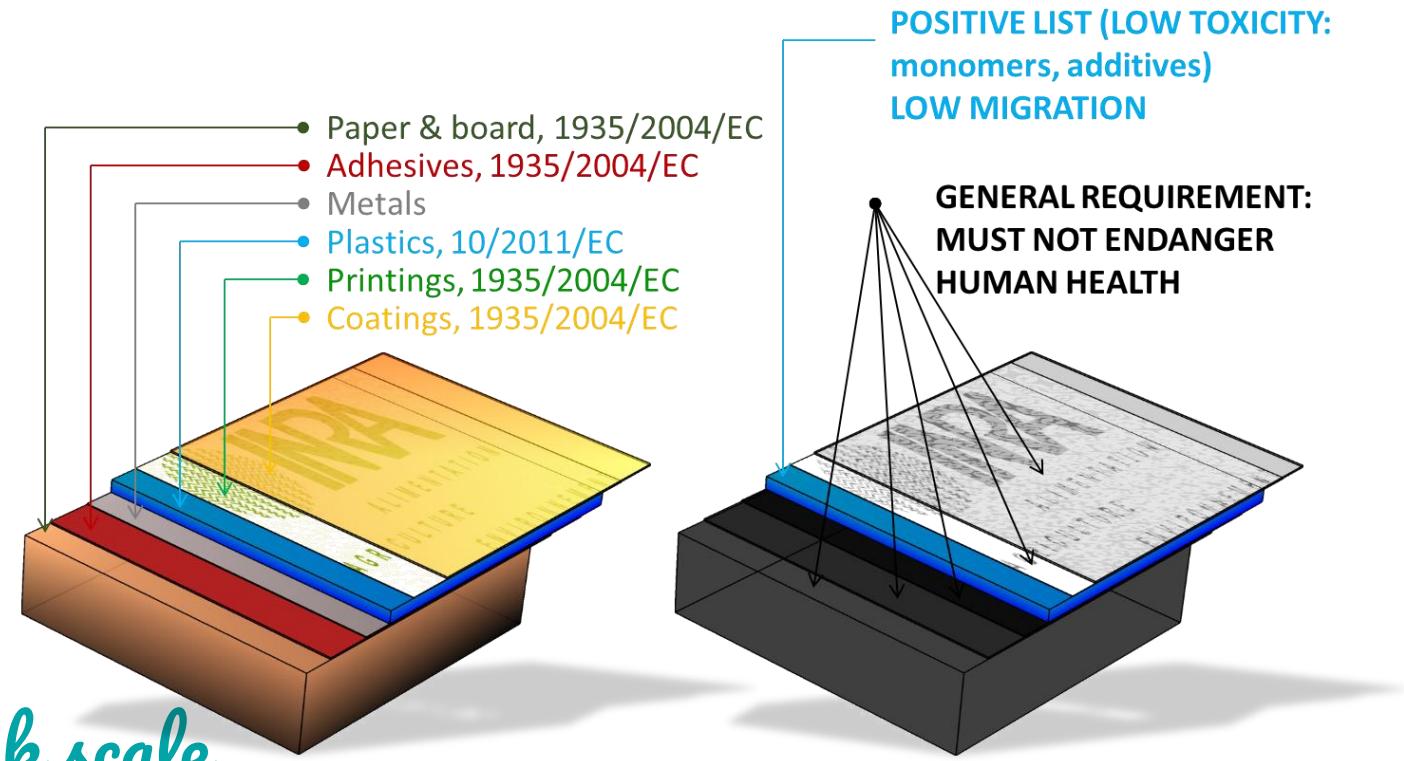
5 Evaluation of existing assessments

The applicant provides information on whether a substance is already approved in a consumer application elsewhere.

Conclusions

EFSA reports its conclusions to the European Commission. If approved, the substance can be used in FCMs. The substance is safe and suitable to be used in food contact according to the descriptions included in the technical dossier.



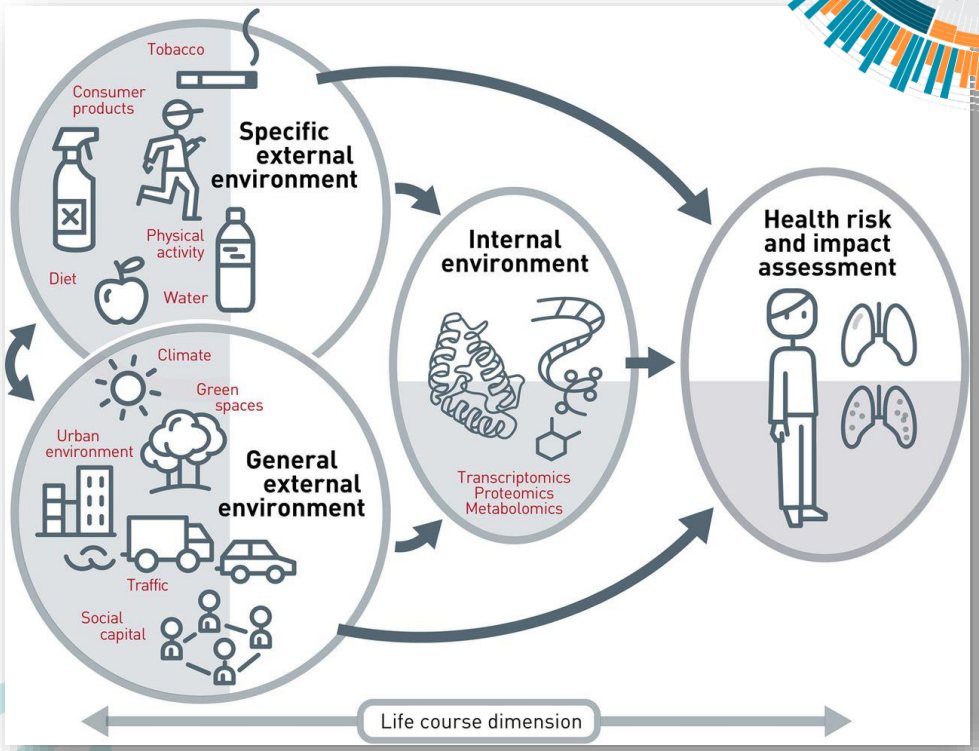


Contradictions and risk scale

The cascade of risk assessment and management

Chronic exposure

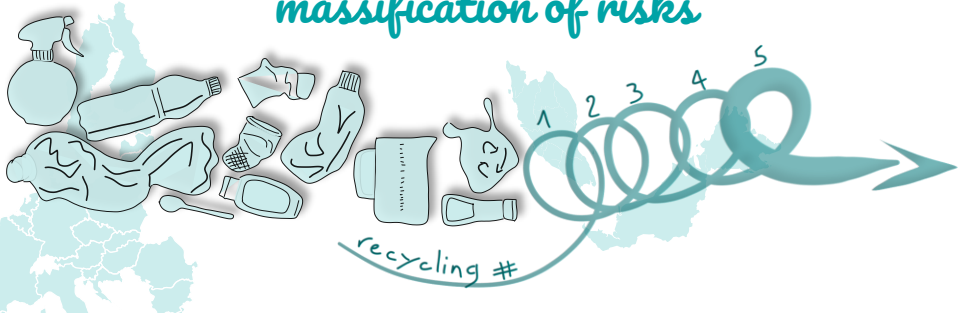
Human exposome



			Risk Tradeoff
		Risk balancing	Conflicts *cognitive, evaluative, normative*
	Scientific risk assessment	Conflict: *evaluative*	
Routine	Conflict: *cognitive*	Targets: BfR, anses, ISTITUTO SUPERIORE DI SANITÀ, FOOD STANDARDS AGENCY, efsa European Food Safety Authority	Targets:DG SANCO, industry stakeholders 
Target: *industry*	Target: *professional associations*		
Discourse: *internal*	Discourse: *cognitive*	Discourse: *reflective*	Discourse: *participatory*
Outcome: simple	***Outcome: complex***	***Outcome: uncertain***	***Outcome: ambiguous***

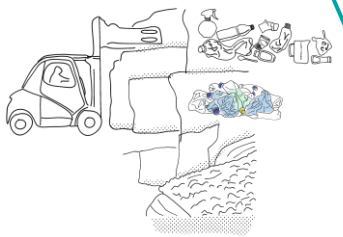
Why a systemic risk?

massification of risks



packaging (material) ⇄ migration / sorption, reactions ⇄ food

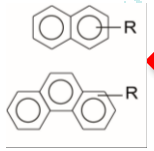
Non-food contact applications +misuse



washing

Contact with recycled materials

« others » (streams)



Why manage risk?

"Risk perception has two main dimensions:

- **the emotional dimension**
- **the cognitive dimension** (how much people know about and understand risks)"

Paek & Hove. *Oxford Encyclopedia of Communication* 2017.

Recycled paper and cardboard for food contact

foodwatch
Test 2015

F

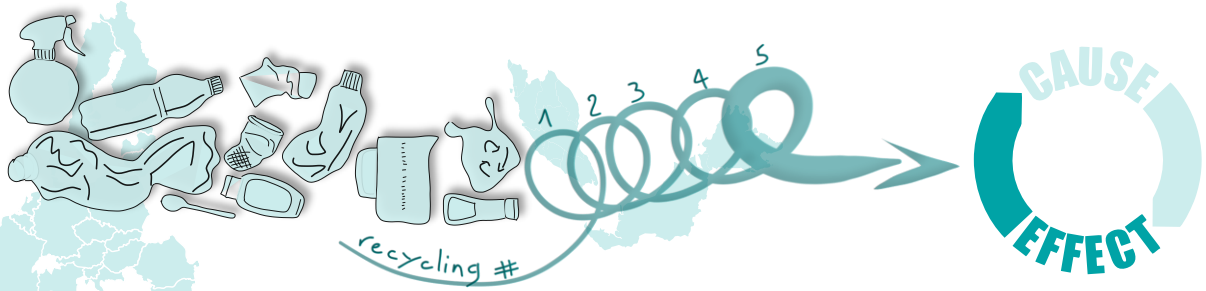
COUSCOUS	Ferrero Graine de Couscous moyen	Tipiak Couscous moyen	Lustucru Semoule de Couscous Facile	Regia Graine de Couscous moyenne	Saint Eloi Couscous Grain moyen (Intermarché)	Carrefour Bio Couscous Grain moyen (Carrefour)	Pouce Vert Couscous Grain moyen (Auchan)
Best-before date	01/05/2017	01/01/2017	01/02/2017	01/03/2017	02/04/2017	01/04/2017	01/03/2017
Packaging material**	Recycled fibre	Fresh fibre	Recycled fibre	Fresh fibre	Recycled fibre	Recycled fibre	Recycled fibre
IN THE PACKAGING							
Saturated mineral oils (MOSH) in mg/kg	296	24	246	271	222	489	237
Aromatic mineral oils (MOAH) in mg/kg	54	<5	48	37	62	138	56
IN THE FOOD							
Saturated mineral oils (MOSH) in mg/kg	1,7	1,2	2,8	1,7	2,4	4,6	2,7
Aromatic mineral oils (MOAH) in mg/kg	0,3	not detectable	0,5	0,3	0,6	1,2	0,4

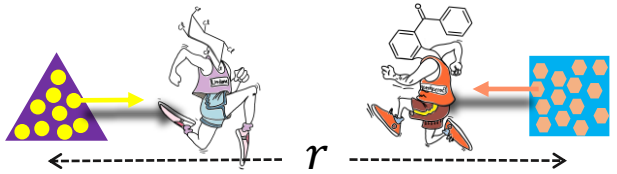
**Hypothesis based on the amounts of MOSH and MOAH found in the packaging.

Why a systemic risk?

massification des risques

Cause = transfer without contact (via air, water)





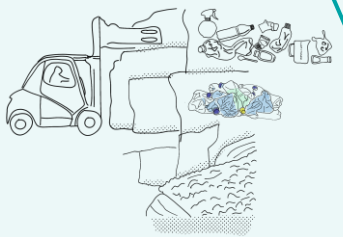
packaging (material)

migration

sorptions, reactions

food

Non-food contact applications +misuse



washing

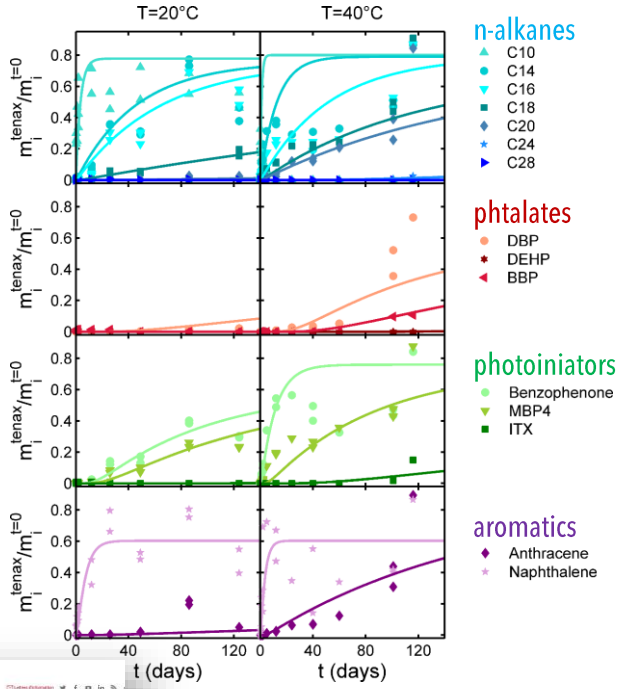
Contact with recycled materials

« others » (streams)

2011-2014

Safe Food Pack Design

Coord. O. Vitrac



Food Additives and Contaminants. 2017,34,1703-20

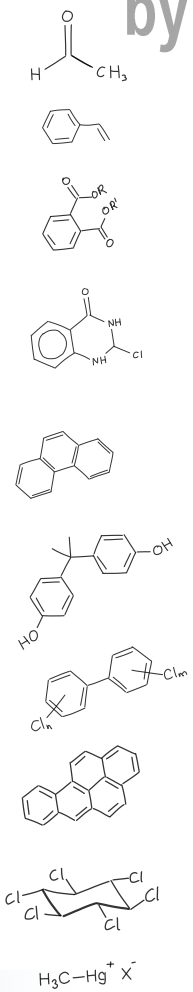
DGCCRF

DGCCRF - Fiche MCDA n°4 (V02 – 01/01/2019)
Contact avec des denrées sèches et non grasses, sans contact physique/mouillage aqueux

https://www.economie.gouv.fr/dgccrf/materiaux-organiques-a-base-fibres-vegetales

European regulations globally unsuited to the circular economy
by material ans substance risk assessment methodology

"Rules do not encourage development of safer and more sustainable alternatives"-
European Commission Workshop Jan 20, 2021 – Evaluation and Revision of EU Rules on Food Contact Materials



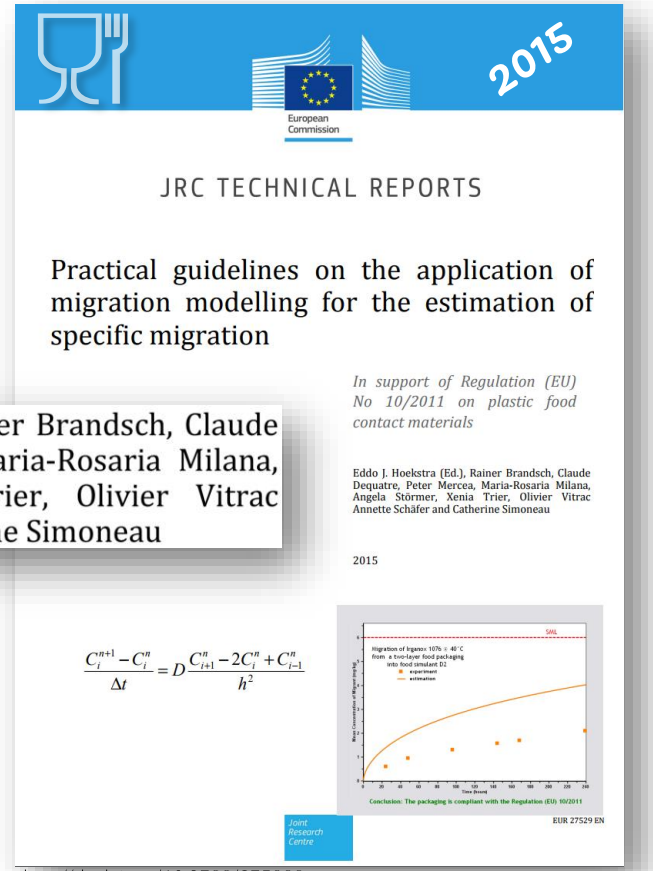
Food-grade recycled plastics

Regulations
10/2011/EC
282/2008/EC
(plastics)

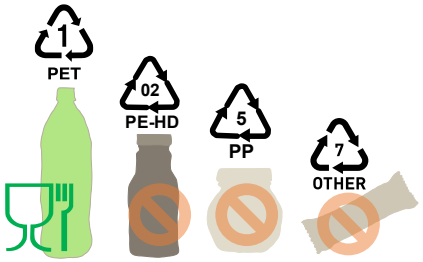
C&en Oct 2021, p. 28

SINGLE USE PLASTICS
DIRECTIVE
2019/904/EC

Plastic wastes



Eddo J. Hoekstra (Ed.), Rainer Brandsch, Claude Dequatre, Peter Mercea, Maria-Rosaria Milana, Angela Störmer, Xenia Trier, Olivier Vitrac Annette Schäfer and Catherine Simoneau



LOI ANTI-GASPILLAGE pour une économie circulaire

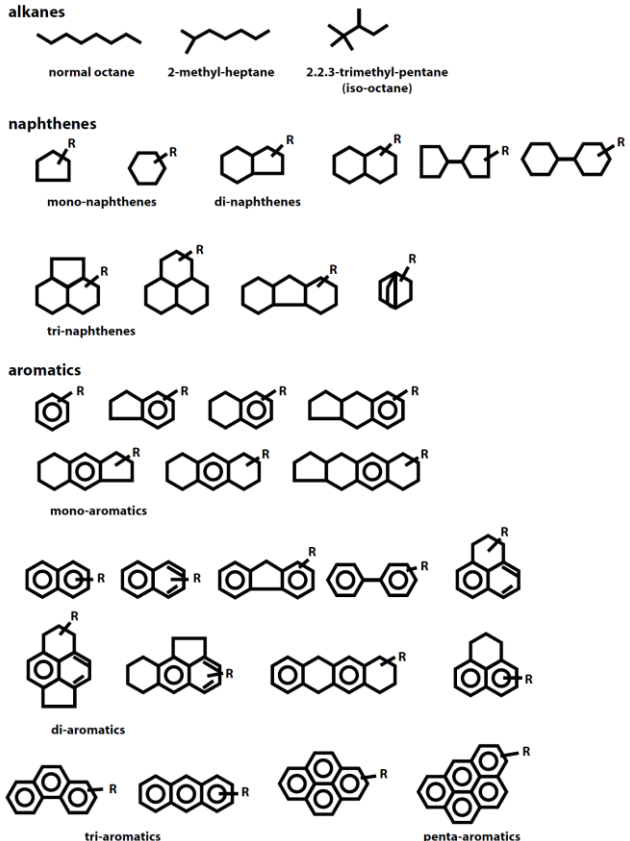
http://dx.doi.org/10.2788/975888

Why a double standard between plastic and cellulosic materials?

Plastics other than PET are not widely recycled for food contact due to safety concerns. Among them, post-consumer polyolefins are heavily formulated, degraded, and contaminated by the previously contacting product

Plastics can be mechanically recyled 9 times with a mandatory decontamination step at each cycle?

Cellulosic materials can be recycled up to 30 times without any decontamination



Key problems identified in EU regulation (consensus)

DG-SANTE, Workshop Jan 20, 2021

- Lack of functioning of the internal market and possible safety issues for non-plastics FCMs.
- Positive authorized list approach and lack of focus on the final article.
- Lack of prioritization of the most hazardous substances and up-to-date assessments.
- Exchange if safety and compliance information in the supply chain is poor and the ability to ensure compliance is compromised.
- Enforcement of rules on FCMs is generally poor.
- Rules do not sufficiently consider the specificity of SMEs.
- Rules do not encourage development of safer and more sustainable alternatives.
- The subject matter is not always clear, and definitions need to be reviewed.

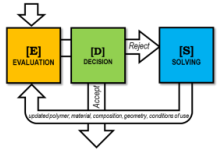
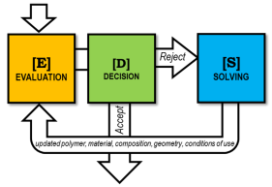
https://ec.europa.eu/food/system/files/2021-01/cs_fcm_eval-workshop_20210120_pres.pdf

Our priorities

ANTI-WASTE LAW for a circular economy

UMT SAFEMAT SAFETY OF PACKAGING

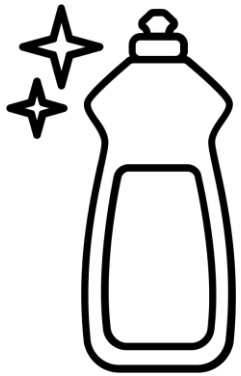
Objectives UMT 22.07

Public Service Mission	Recycle	Reduce	Reuse
Support the evolution of European regulations + anti-waste decrees		No contribution	
Supporting the substitution of materials			
Secure the product and ensure the performance of the packaging			

Objectives of the 3Rs Decree

Example of contamination levels of PET bottles recollected from non-food contact applications

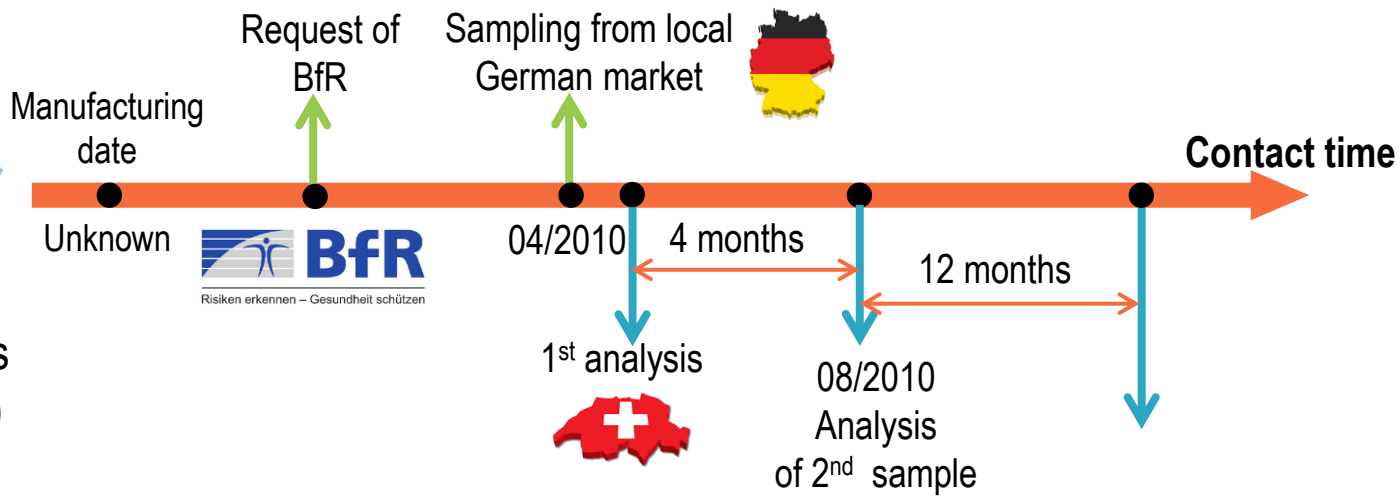
Substances found in PET bottles originally used for dishwashing products – *Molecules* **2020**, *25*(21), 4998

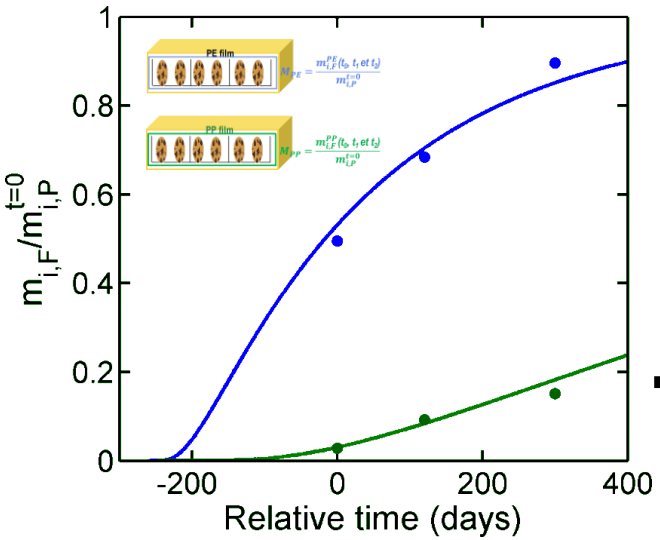


Substance (mol.weight [g/mol])-*CAS-No.*	GC R_t [min]	Cramer Classification Class I	Class II	Class III	Alert gtc	Alert ngtc	Concentration in PET [mg/kg] Sample No. 1	2	3	4	5	6	Mean 1–6
Ethanol (78.4)-*64-17-5*	1.8	x			-	-				380			63.3
Unknown 1	1.8	?	?	?	?	?						2.0	0.33
2-Butanone (79.6)-*78-93-3*	2.1	x			-	-				7.5			1.25
2-Methyl-1,3-dioxolane (88.1)-*497-26-7*	2.4	x			-	-	0.4	1.5	1.8	0.3	1.0	0.8	0.97
n-Butanol (74.1)-*71-36-3*	2.5	x			-	-		0.5					0.08
Benzene (78.1)-*71-43-2*	2.5			x*)	-*)	-*)					0.9		0.15
Ethylene glycol (62.1)-*107-21-1*	2.7	x			-	-	2.1	5.1	3.0	3.3	3.2	3.1	3.3
Toluene (92.1)-*108-88-3*	3.9			x	-	-				2.4			0.4
o-Xylene (106.2)-*95-47-6*	5.6			x	-	-			0.3				0.05
m-Xylene (106.2)-*108-38-3*	5.8			x	-	-			0.6				0.1
Benzaldehyde (106.1)-100-52-7	5.8	x			+*)	-				0.6			0.1
p-Xylene (106.2)-*106-42-3*	6.1	x			-	-			0.1				0.02
Acetic acid hexylester (144.2)-*142-92-7 (n)* or *628-95-5 (iso)*	7.8	x			-	-				0.7			0.12
Limonene (136.2)-*7705-14-8*	8.1	x			-	-	0.7		1.6				0.38
Nonanal (142.2)-*124-19-6*	8.8	x			+*)	-	0.4		0.2	0.3		0.3	0.2
Unknown 2	8.9	?	?	?	?	?		2.5					0.42
Benzoic acid (122.1)-*65-85-0*	9.3	x			-	-				3.3			0.55
Acetic acid benzylester (150.2)-*140-11-4*	9.3	x			-	-					2.6		0.43
Decanal (156.2)-*112-31-2*	9.8	x			+*)	-	0.2	0.2	0.4	0.2			0.17
Phenoxymethanol (124.1) or	9.8			x	-	-						13	2.2
Salicylalcohol (2-hydroxymethyl phenol) (124.1)-*90-01-7*		x			-	-							
2-Hydroxy-4-methyl benzaldehyde (136.2)-*698-27-1*	10.1	x			+*)	-					0.4		0.07
1-Phenoxy ethanol (138.2)-*122-99-6*	10.1		x		-	-						8.4	1.4

x: Cramer classification; ?: classification not possible due to unknown substance; -: negative alert; +: positive alert; *) wrong assignments by Toxtree: benzene is a known human carcinogen; benzaldehyde is not a human carcinogen and not genotoxic; nonanal and decanal: not human carcinogens, JECFA/DG Sante authorized food flavouring agents; 2-hydroxy-4-methyl benzaldehyde = 4-methyl salicylaldehyde: EU Food Additive—Flavis no. 05.091.

119 dry food products
(3 samples/category)
Biedermann et al. (2013)





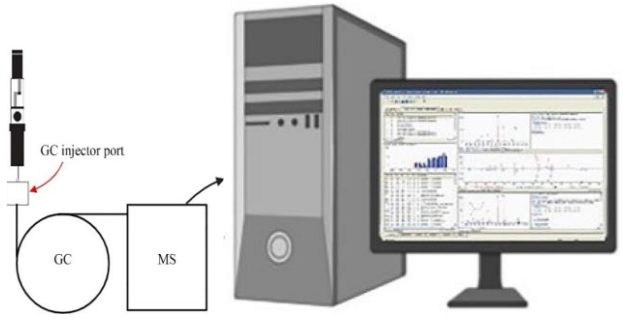
$$\rightarrow \frac{M_{PE}}{M_{PP}} \propto \frac{D_{i,PE}}{D_{i,PP}}$$

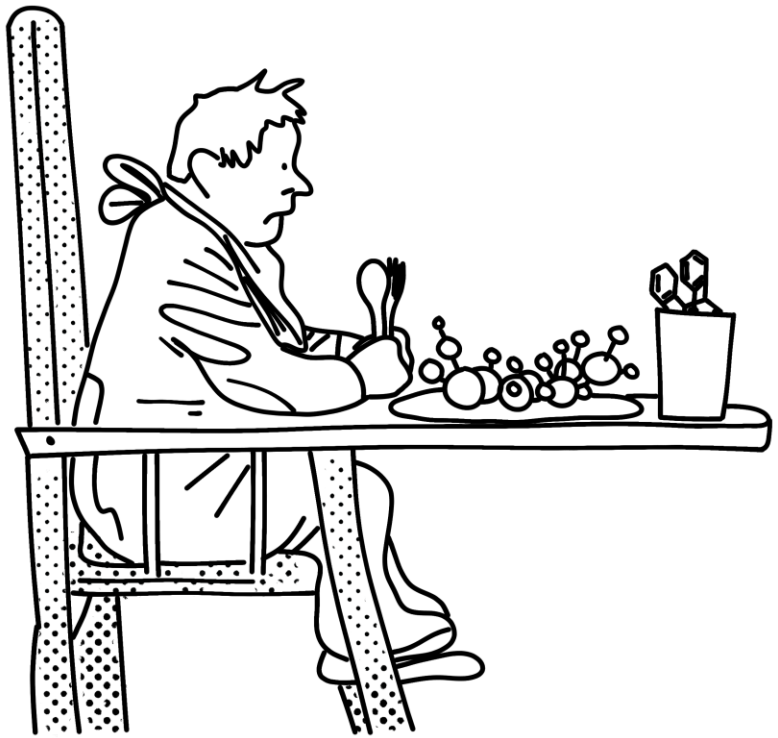
Paper and board = prevalent source of chemical contaminants in food

Mineral Oils, Printing inks, adhesives

Revisiting the principles of safety assessment

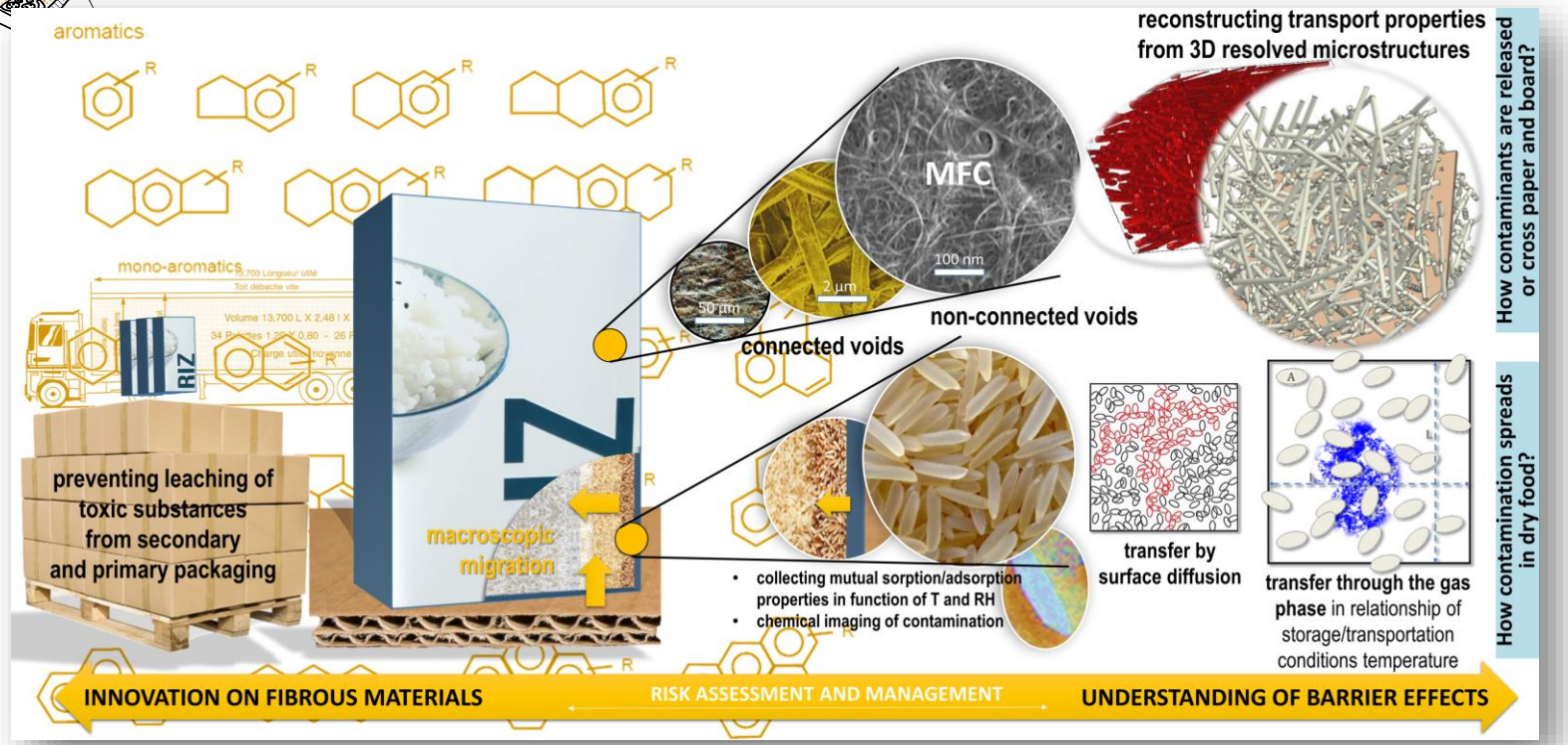
Looking for viable strategies



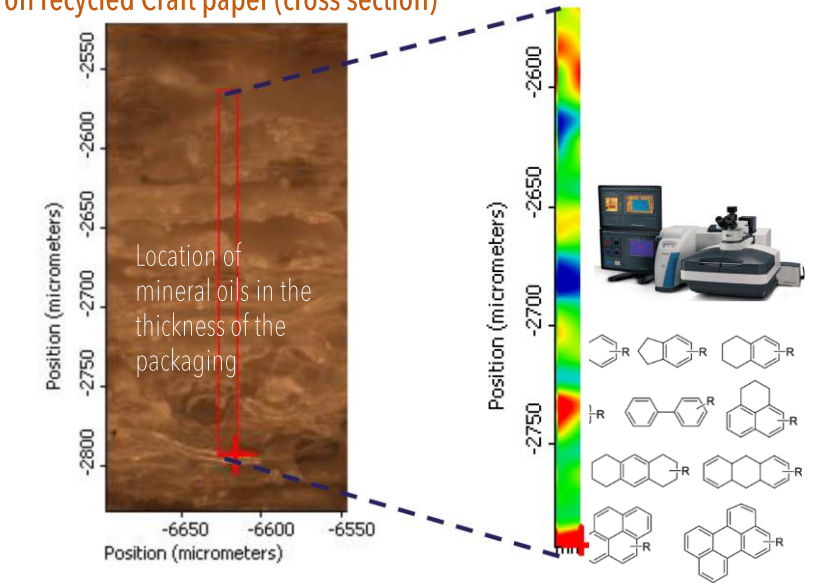


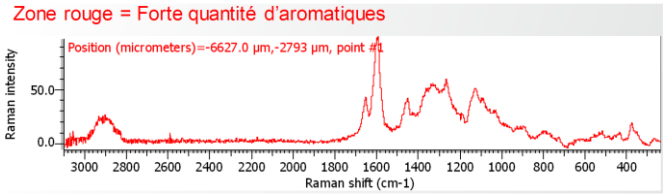
- **Traceability of sourcing, managing cross-contamination** during collection, sorting and recycling
- **Risk assessment and management of unknown chemicals (NIAS)** via consumer exposure
- **Unknown acceptable thresholds** (acute toxicity, endocrine disruptors, cocktail effects)
- **The aging of materials** needs to be considered
- **Functional barrier?** virgin/recycled/decontaminated? which solution? How to evaluate them? Which service life?
- **Evaluating migration / exposure** below the detection limit
- **Migration modeling** is the only viable approach but which contamination level to consider?

(2021-2024, coord. O. Vitrac) – Illustration of the scientific approach



Chemical imaging (Raman)
on recycled Craft paper (cross section)





T1. Production of reference materials

T2. Characterization of materials and functional barriers

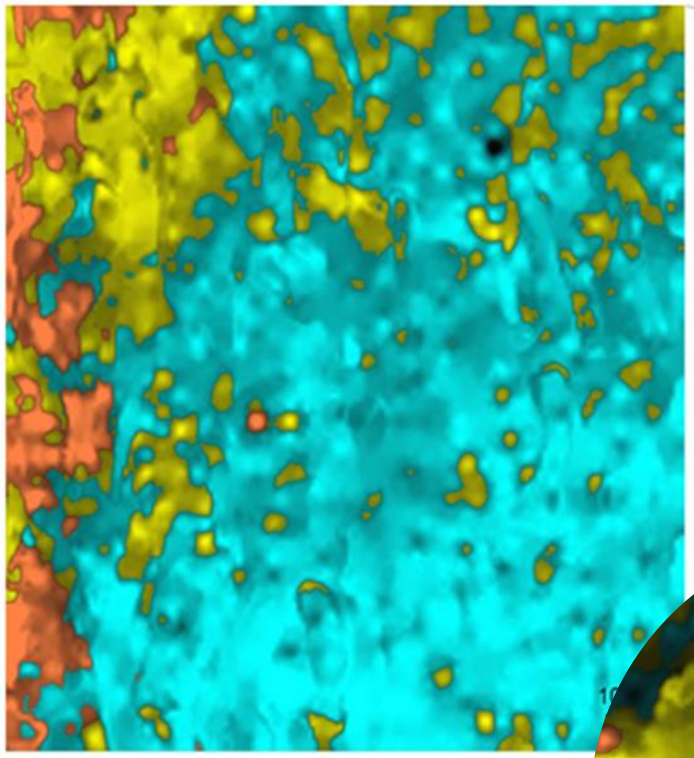
T3. Direct/indirect characterization of streams

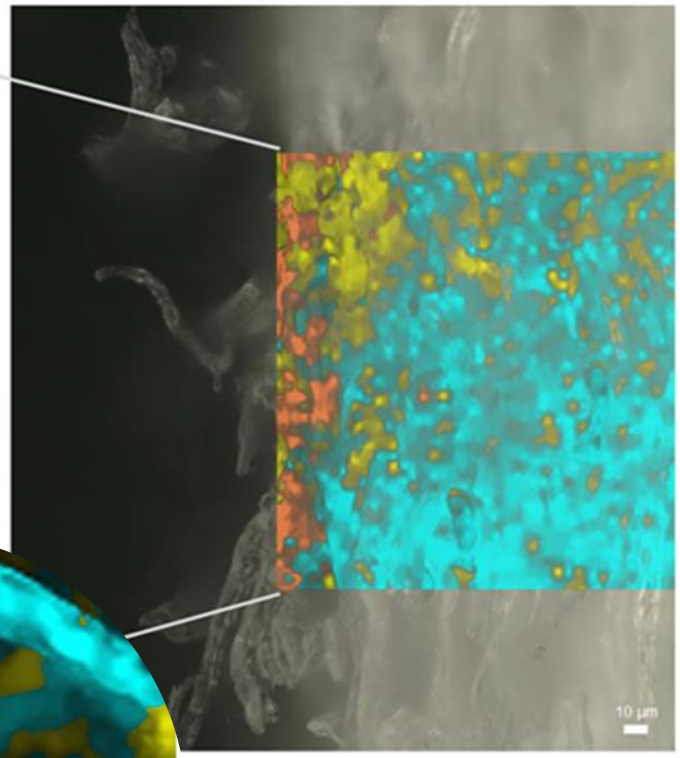
T4. Thermodynamic characterization of mass transfer

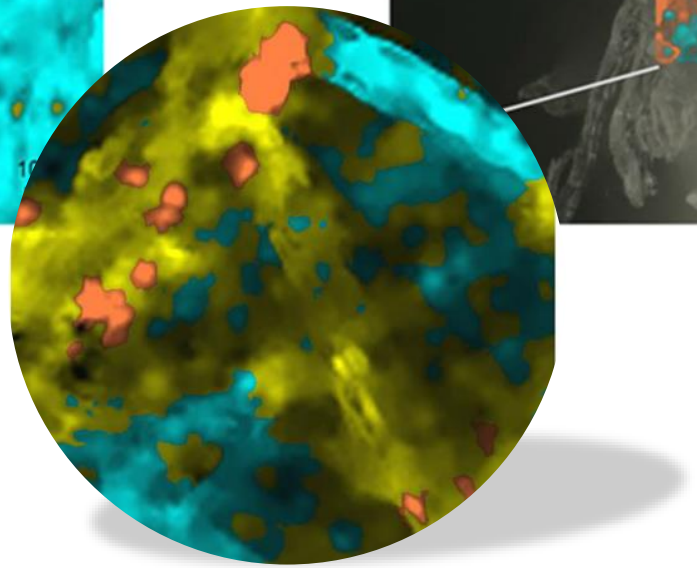
T5. Multiscale transfer modeling / validation

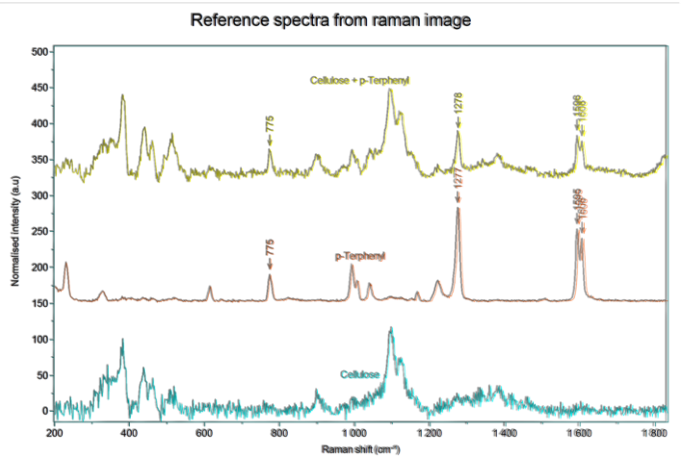
T6. Risk assessment and performance optimization

Chemical imaging – Raman spectroscopy on paper

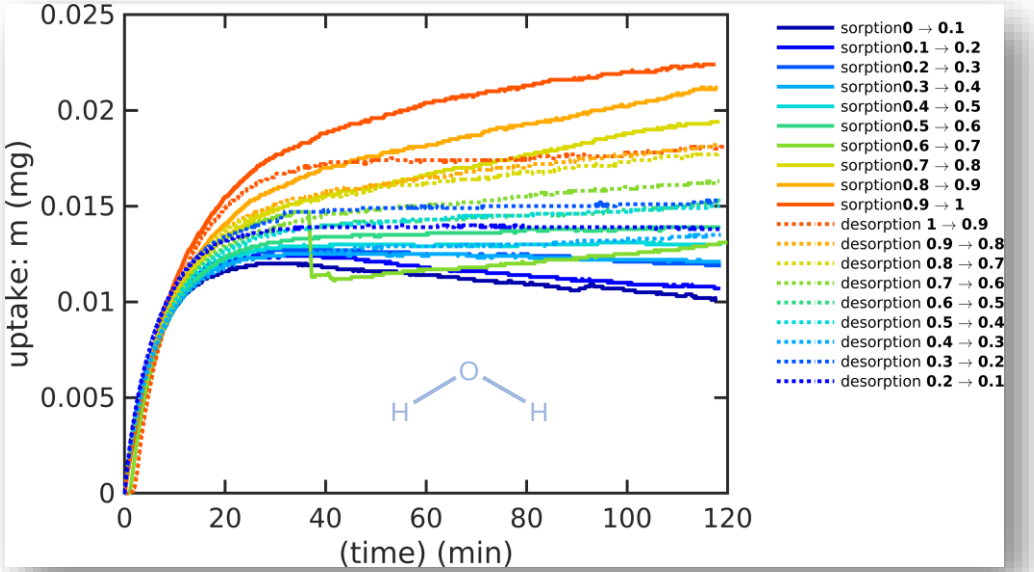




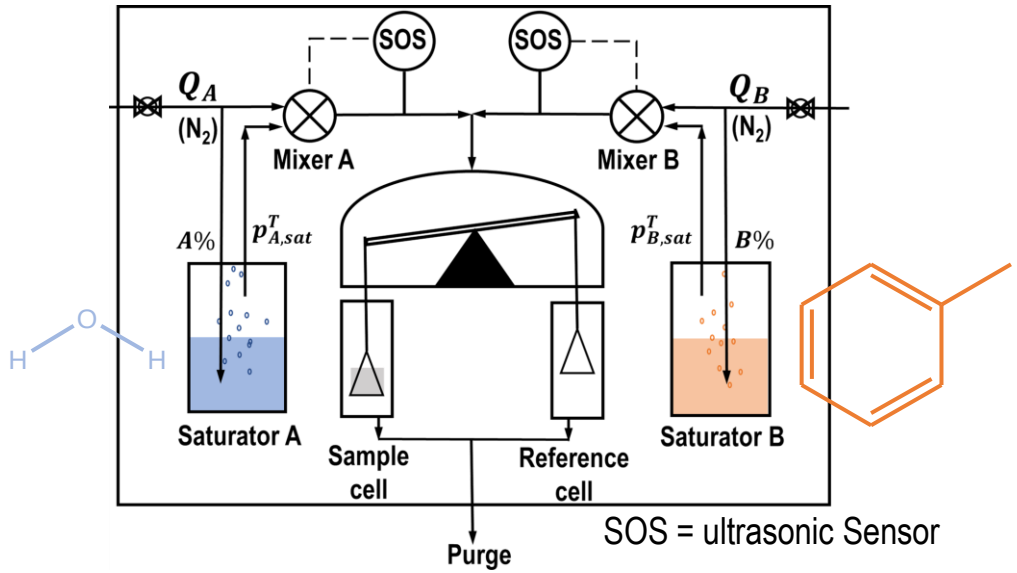


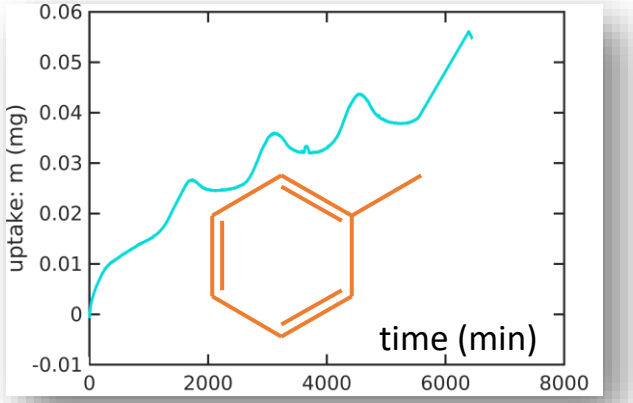


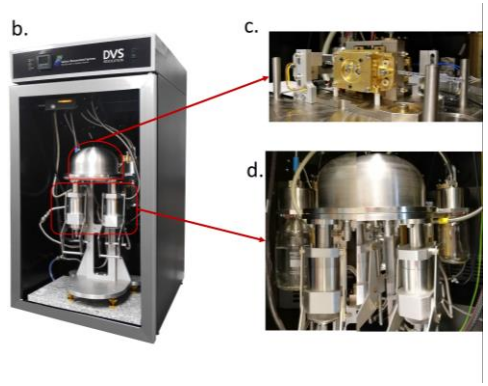
Thermodynamic measurements (e.g. 25 µm thick - PET)



Automatic microbalance



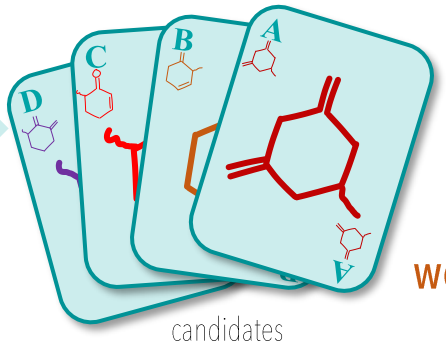




The challenge of NIAS

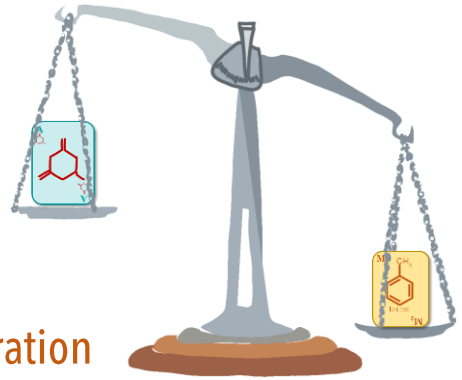
Propagating uncertainty with the risk that no decision can be reached

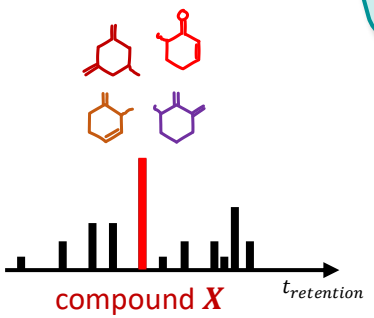
exposure assessment

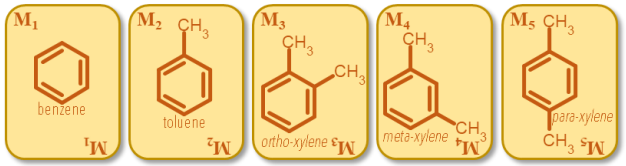


candidates

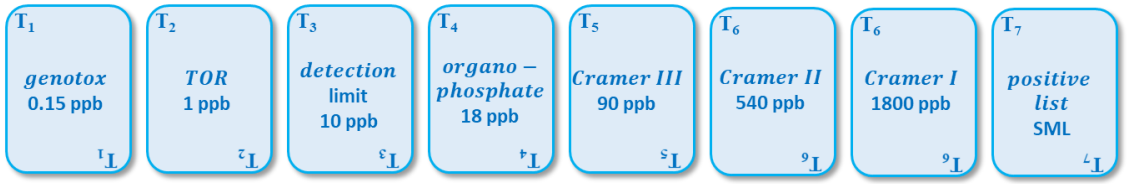
worst-case migration





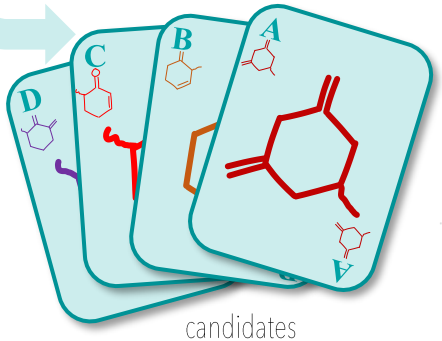


$\hat{C}_F$

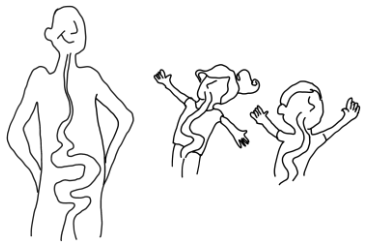


$\hat{T}$

hazard analysis

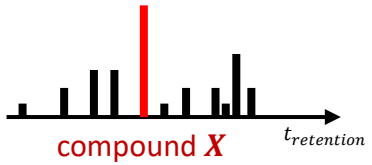


candidates

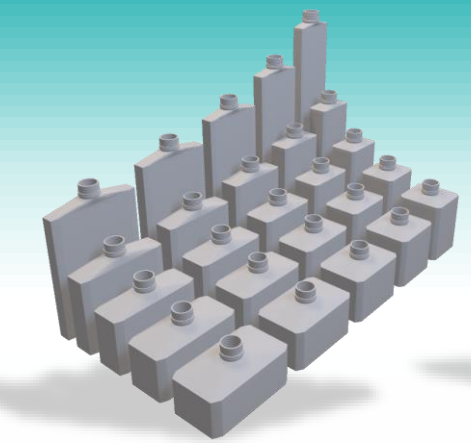


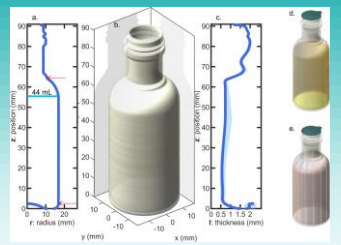
acceptable threshold

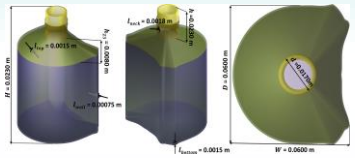
$$\textbf{\textit{Severity}}(\boldsymbol{X}) = 100 \times \max\left(\frac{\hat{C}_F^A}{\hat{T}_A}, \frac{\hat{C}_F^B}{\hat{T}_B}, \frac{\hat{C}_F^C}{\hat{T}_C}, \frac{\hat{C}_F^D}{\hat{T}_D}\right)$$

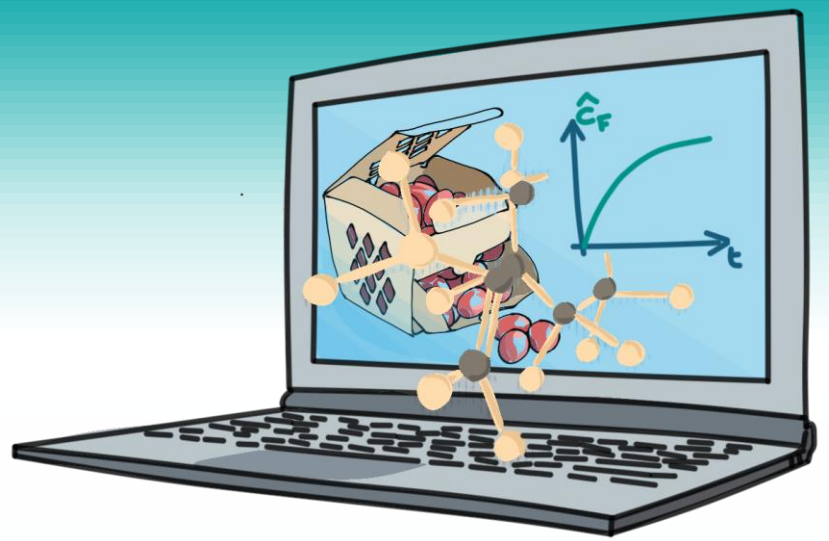


all compounds



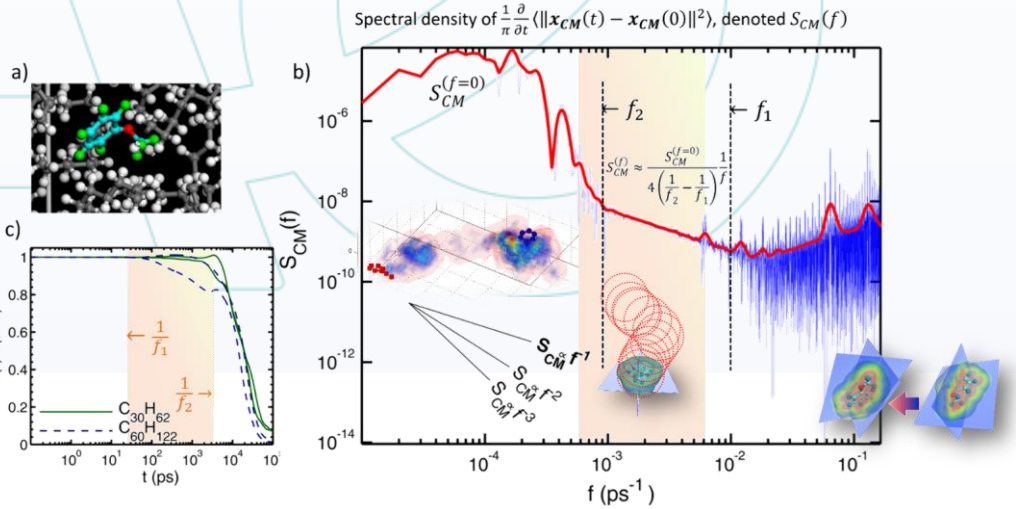


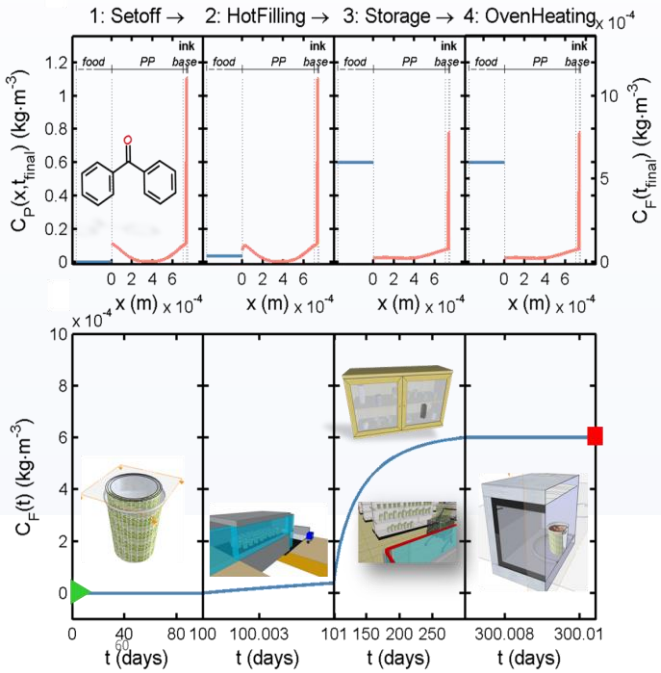


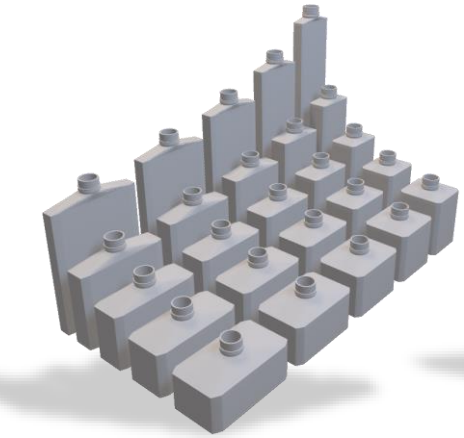


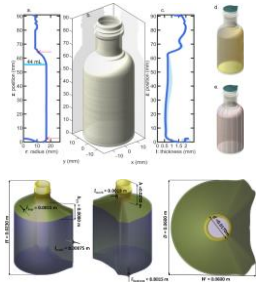
Migration modeling and computational engineering

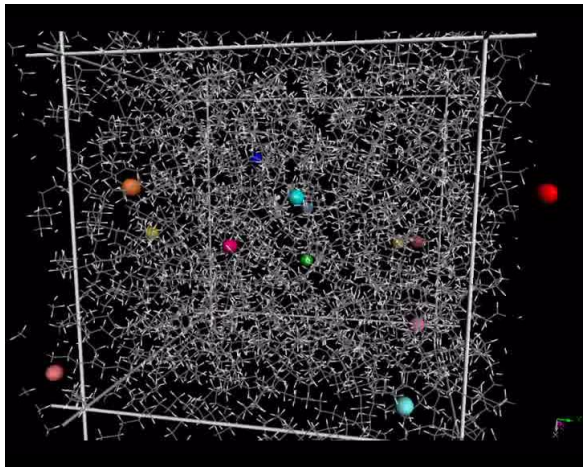
OUR WAY OUT

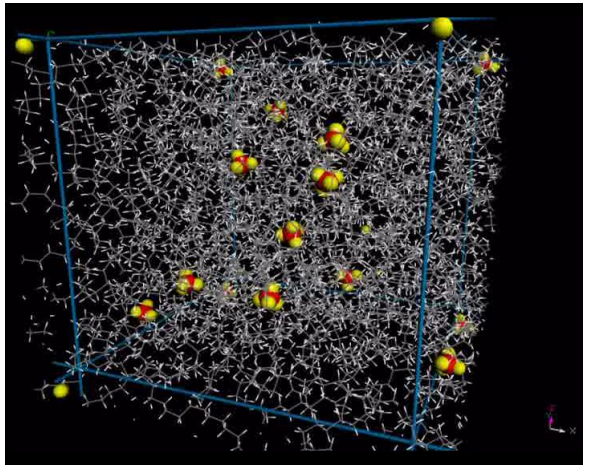






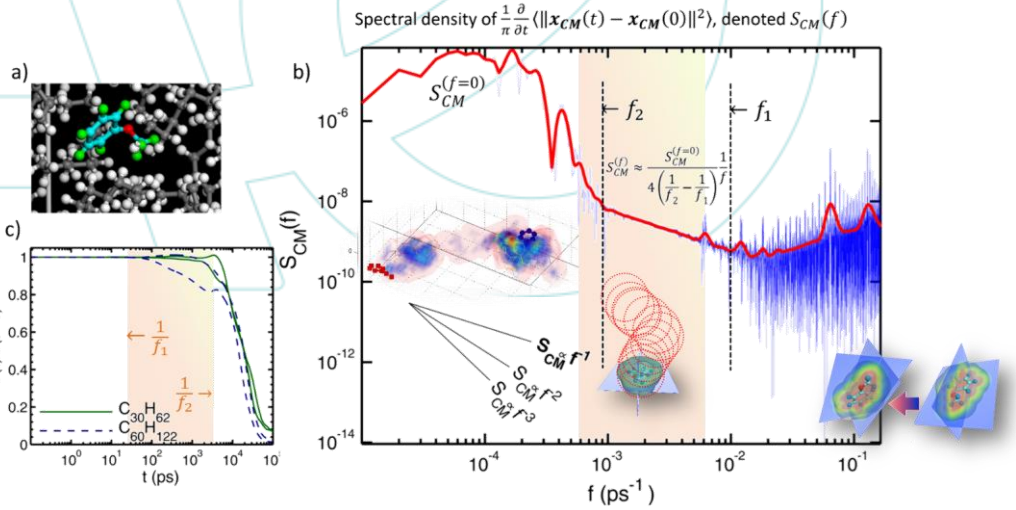


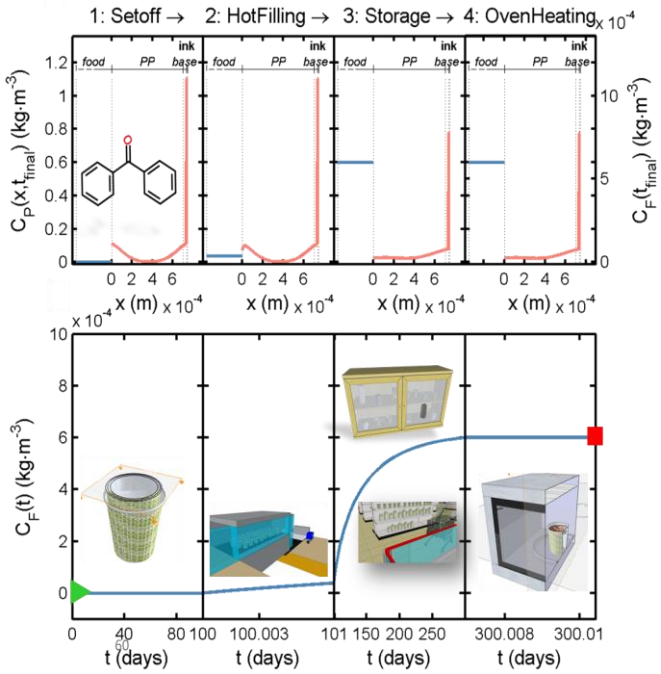


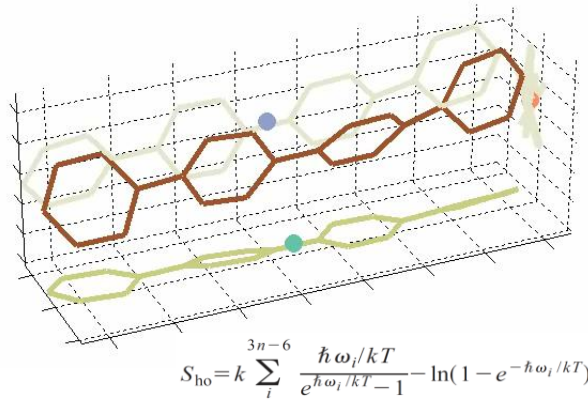


Migration modeling and computational engineering

OUR WAY OUT







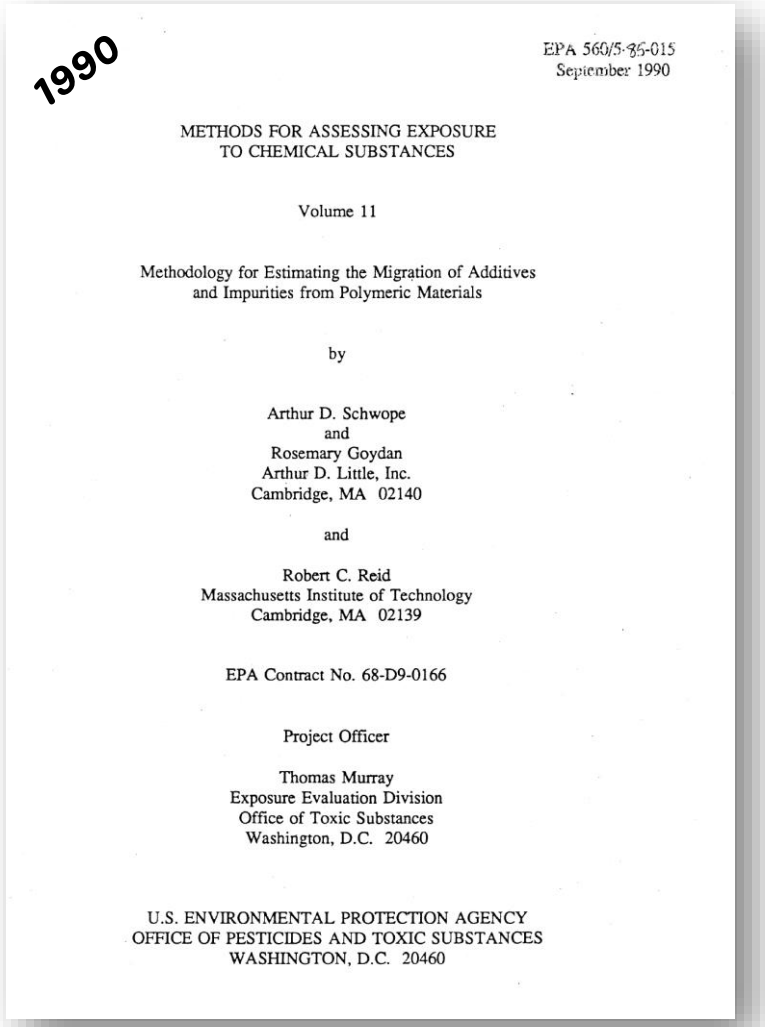
$$S_{ho} = k \sum_{i}^{3n-6} \frac{\hbar\omega_i/kT}{e^{\hbar\omega_i/kT}-1} - \ln(1-e^{-\hbar\omega_i/kT})$$

Migration modeling is well accepted in the US, Europe and China

Revisions and to extensions to non-plastic materials are pending

US guidance

Methodology for Estimating the Migration of Additives and Impurities from Polymeric Materials



1990

EPA 560/5-86-015
September 1990

METHODS FOR ASSESSING EXPOSURE
TO CHEMICAL SUBSTANCES

Volume 11

Methodology for Estimating the Migration of Additives and Impurities from Polymeric Materials

by

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Project Officer

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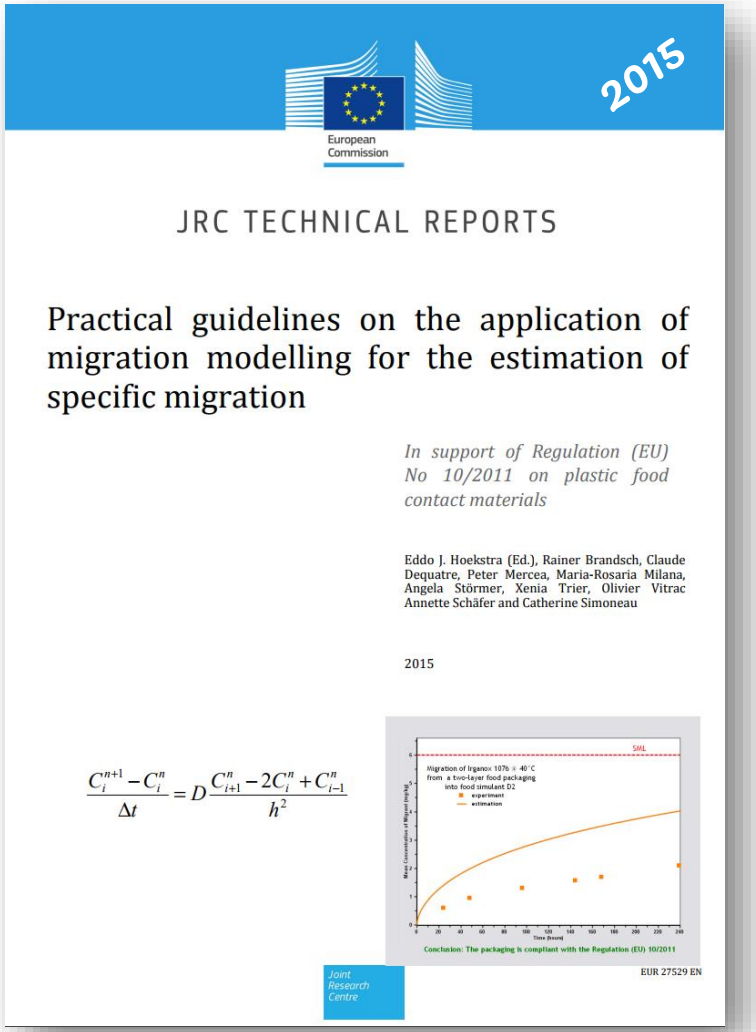
U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF PESTICIDES AND TOXIC SUBSTANCES
WASHINGTON, D.C. 20460

https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100BCMB.TXT



2015

European Commission

JRC TECHNICAL REPORTS

Practical guidelines on the application of migration modelling for the estimation of specific migration

In support of Regulation (EU) No 10/2011 on plastic food contact materials

Eddo J. Hoekstra (Ed.), Rainer Brandsch, Claude Dequatre, Peter Mercea, Maria-Rosaria Milana, Angela Störmer, Xenia Trier, Olivier Vitrac Annette Schäfer and Catherine Simoneau

2015

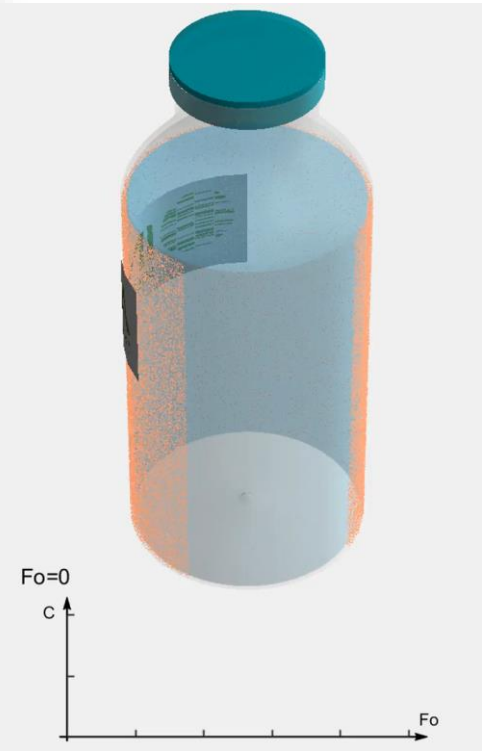
$$\frac{C_i^{n+1} - C_i^n}{\Delta t} = D\frac{C_{i+1}^n - 2C_i^n + C_{i-1}^n}{h^2}$$

Joint Research Centre

EUR 27529 EN

http://publications.jrc.ec.europa.eu/repository/handle/JRC98028

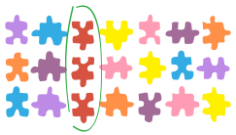
Europe guidance



The five principles of migration modeling

- *The first principle* ("**conservatism**") is that modeling and related calculations should overestimate the real migration or contamination.

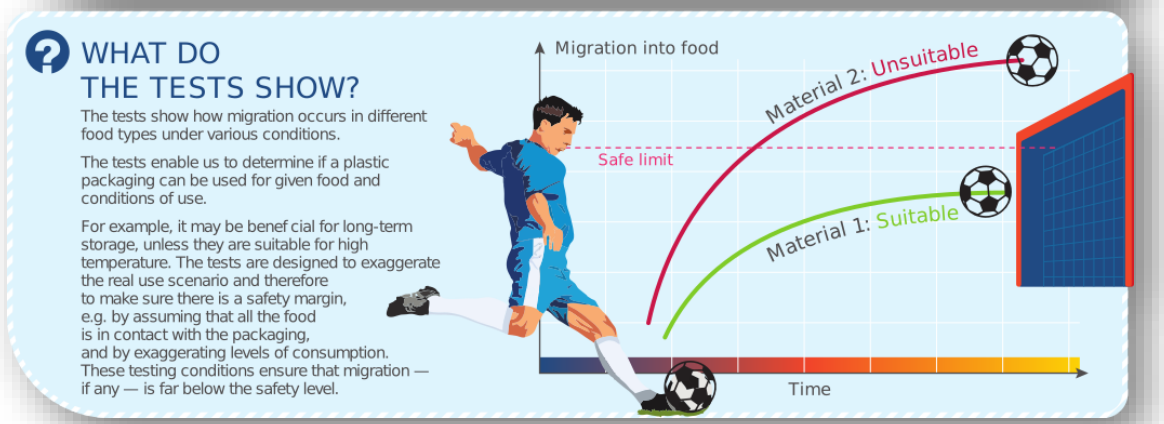
- *The second principle* ("**reliability**") implies that the foreseen mass transfer pathways and substances obey well-described mechanisms, accepted conditions (e.g., uniform distribution), and proper implementation in software.



- *The third principle* ("**consistency**") is that inputs in the model are known or guessed in a way that fulfills the requirements of the first principle.

- *The fourth principle* ("**parsimony**") states that sophisticated and refined scenarios should be considered only when simpler ones cannot demonstrate compliance or safety.

- *The fifth and final principle* ("**proportionality**") is that non-compliance cannot be demonstrated by calculation.

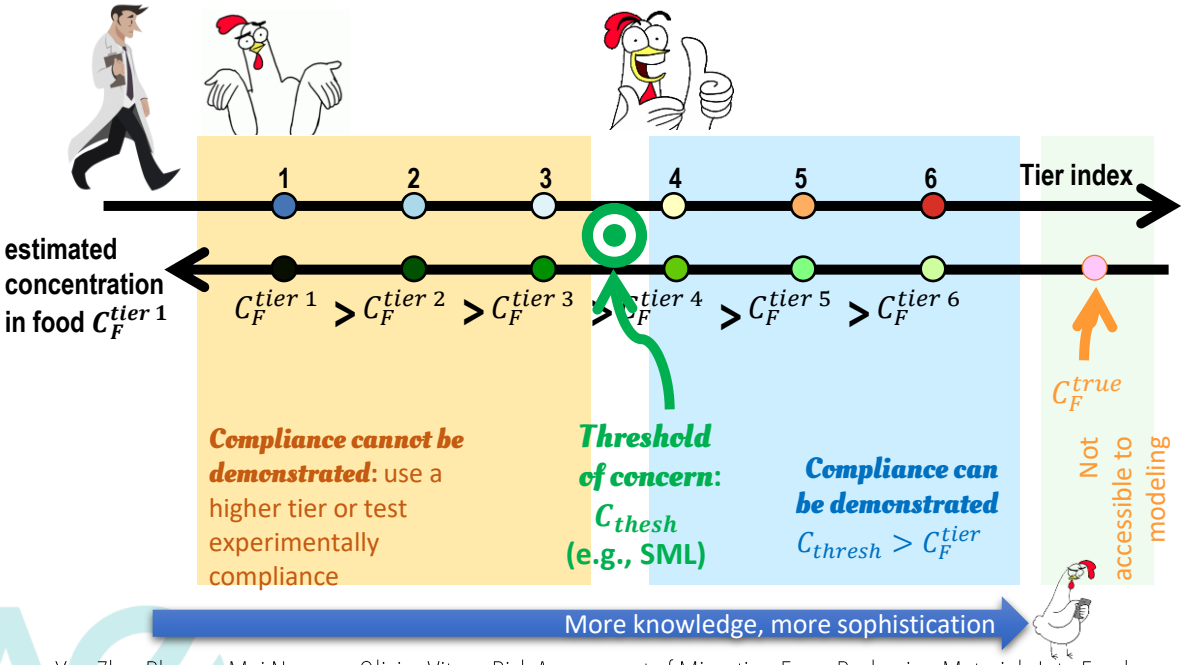


Parsimony vs. sophistication

During the last decade migration modeling became high throughput, multiscale and connected to chemometric approaches

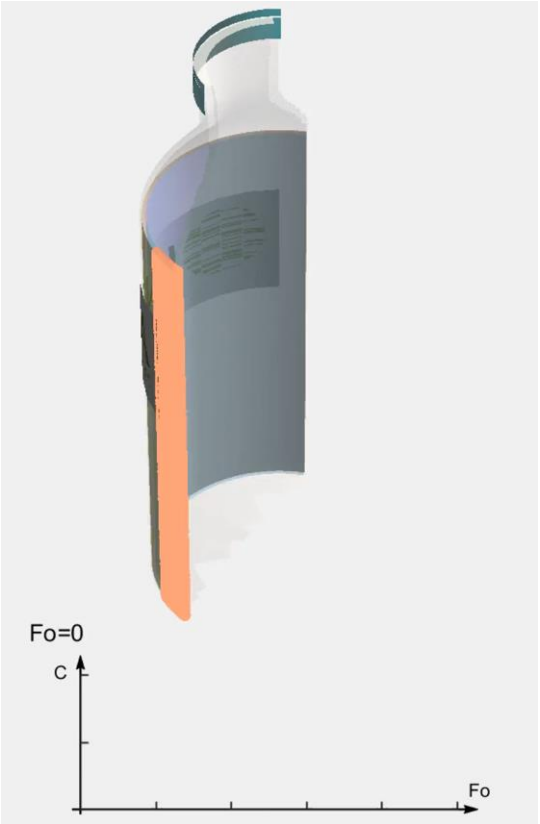
What is the goal?

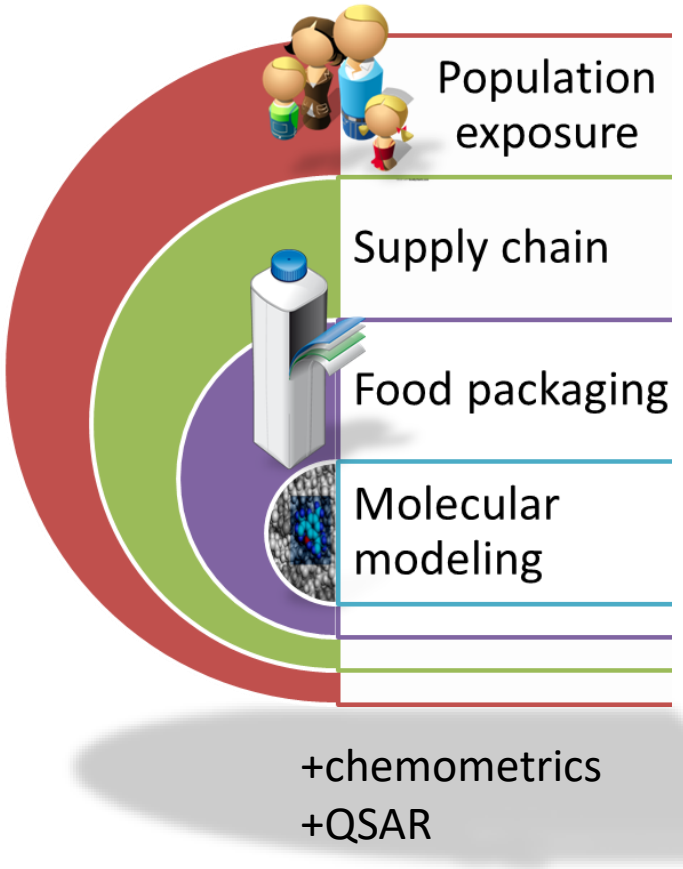
The art of migration modeling consists in building a sequence of scenarios so that the last scenario provides a value lower than the threshold of concern while being large than the real concentration (unknown).



Yan Zhu, Phuong-Mai Nguyen, Olivier Vitrac, Risk Assessment of Migration From Packaging Materials Into Food, Reference Module in Food Science, Elsevier, 2019, https://doi.org/10.1016/B978-0-08-100596-5.22501-8.

Multiscale modeling

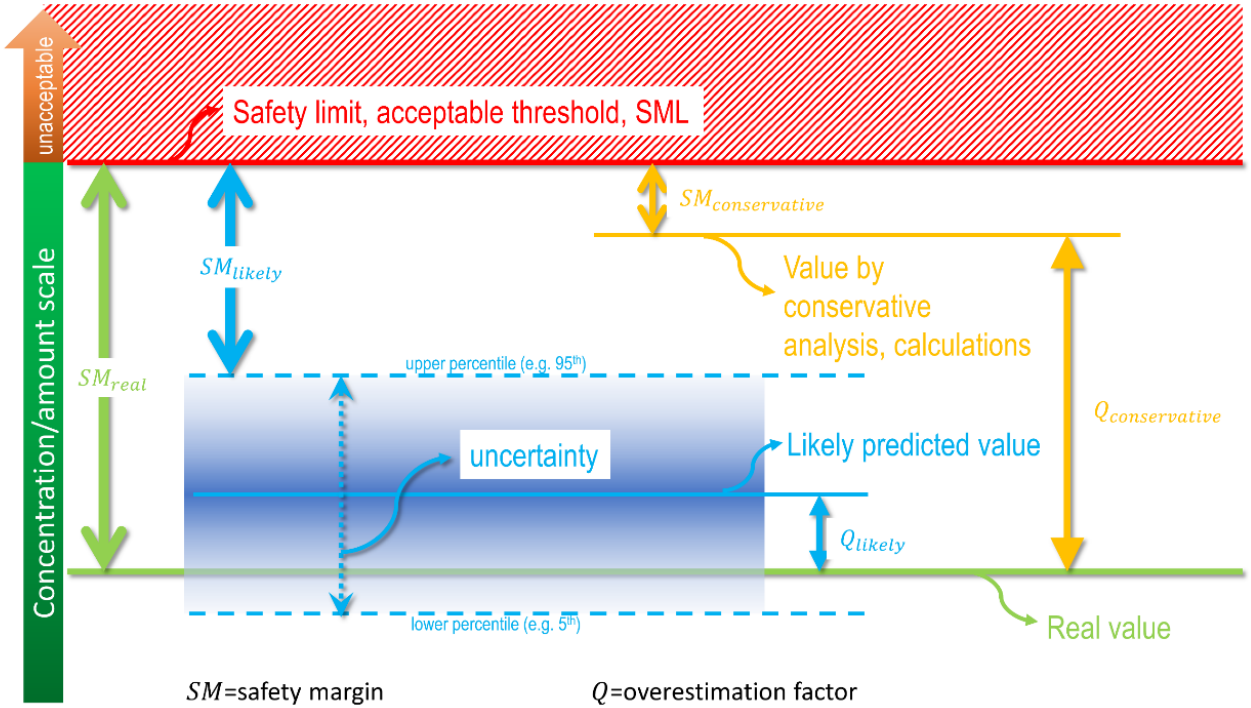


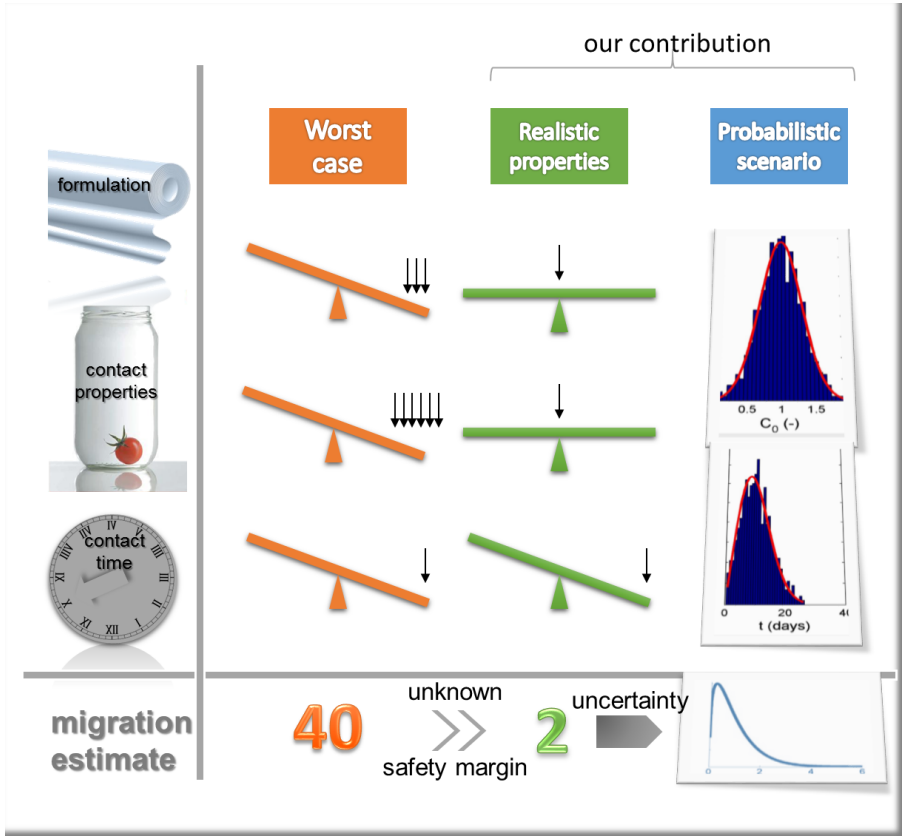


How to manage uncertainty ?

Uncertainty vs *ignorance*

- "*scientia*" (science) vs "*opinio*" (belief)
- Conventional modeling assumes complete knowledge and epistemologic transformation of information into knowledge.
- How to code "vagueness", "skeptism", "error", "doubt"





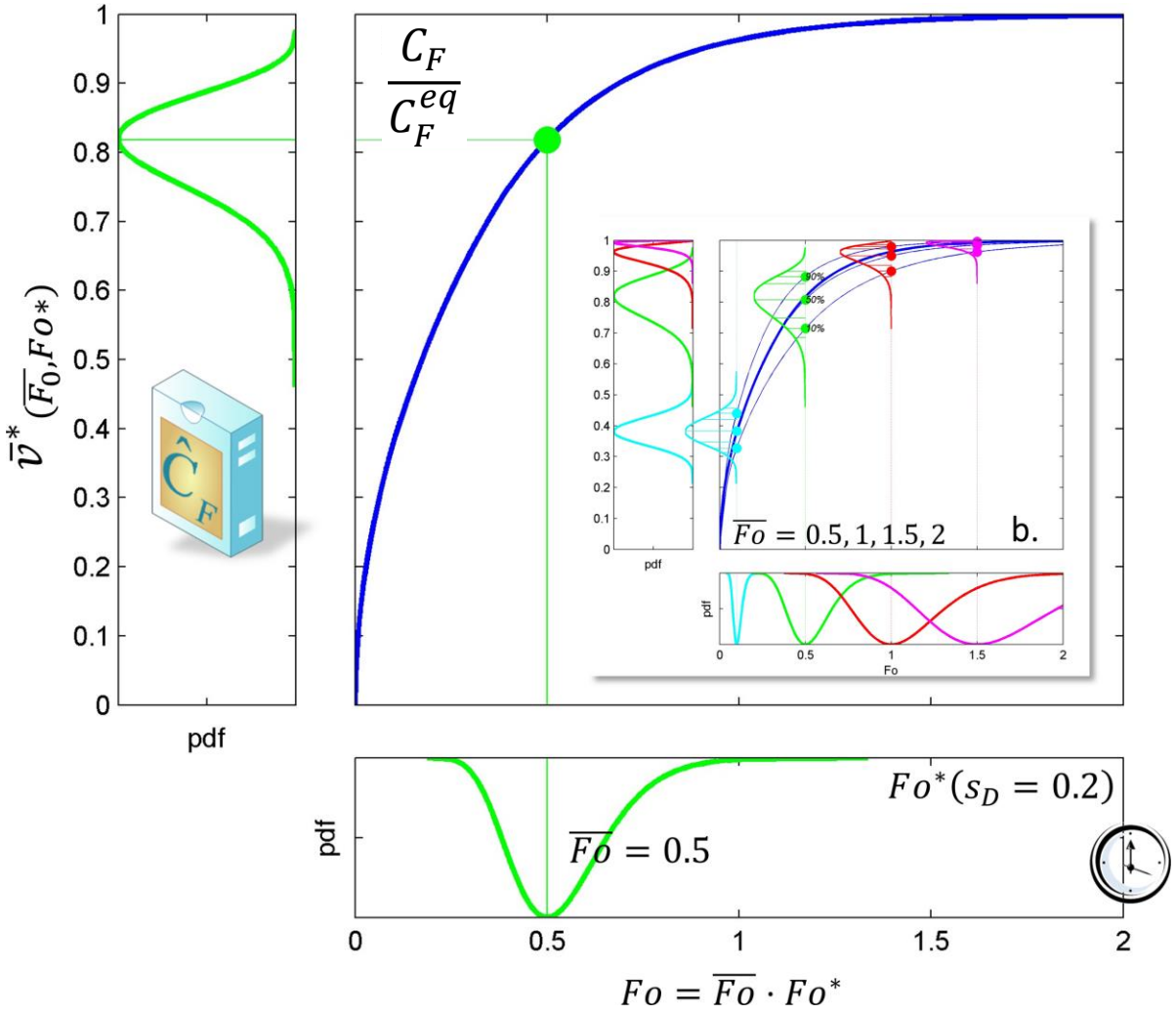
Probabilistic modeling

Probabilistic modeling

- Part of best practices
- "Mandatory" for risk assessment
- Uncertainty ≠ variability, it can be reduced by additional knowledge or model details.
- Monte-Carlo sampling can be avoided in several situations to reach almost real time simulation.

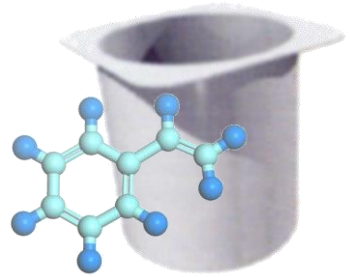
$$f_{\bar{v}^*}(v) = \sum_{k=1}^{p} f_{Fo}\left(\bar{v}^{*-1}\big|_{Fo\in Y_k}(v)\right)\left|\frac{d}{dv}\bar{v}^{*-1}\big|_{Fo\in Y_k}(v)\right|^{-1}$$

E.g., monotonic model



O. Vitrac and M. Hayert, *Aiche Journal* ***2005, 51, 1080-1095.***
O. Vitrac, B. Challe, J.-C. Leblanc and A. Feigenbaum, *Food Additives and Contaminants t* ***2007, 24, 75-94.***

Styrene from yoghurt pots: an example of forecast

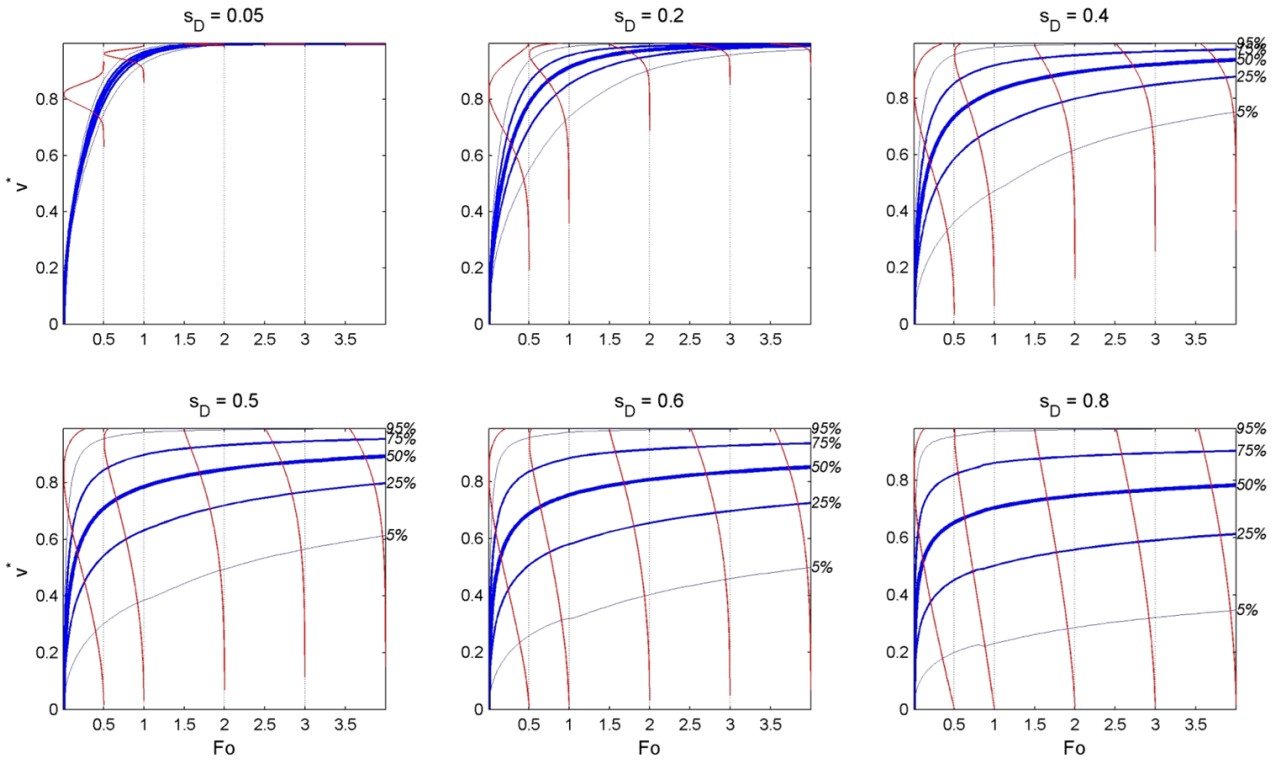


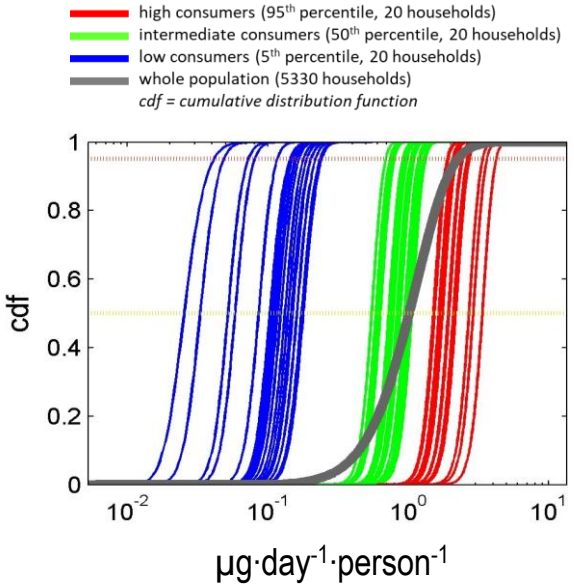
$$p_{\underset{product\ scale}{r}}\ C \le x\ = f\begin{pmatrix}\text{food, packaging, migrants}\\ \text{storage cond., uncertainty}\end{pmatrix}$$

$$p_{\underset{household\ scale}{r}}\ E \le y\ = g\begin{pmatrix}\text{food products, packaging materials, migrants}\\ \text{storage conds., uncertainty}\\ \text{consumption scenarios}\end{pmatrix}$$

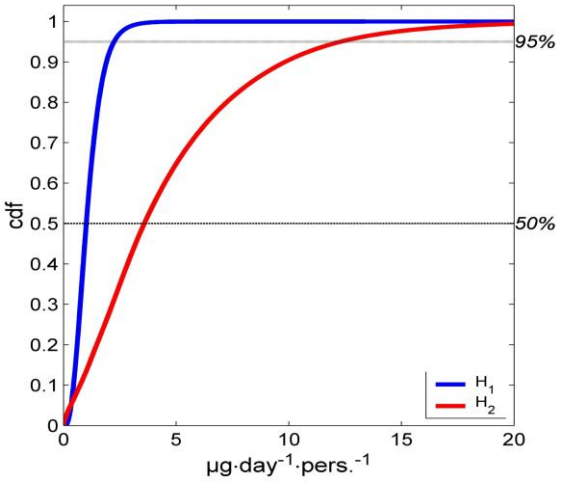
$$E_k = \frac{c_0 \cdot \overline{v}_\infty^*}{365 \cdot P_k} \cdot \sum_{i=1}^{N_k} \overline{v}_i^* \quad Fo_i, Bi, K, L$$

6122 Households
221,190 Purchases
1,930,257 Purchased units

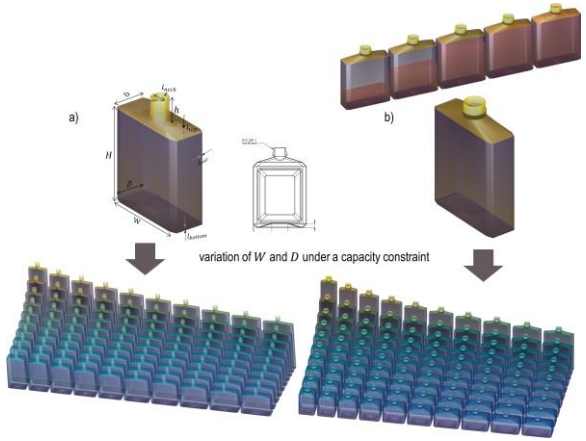




2 physico-chemical scenarios

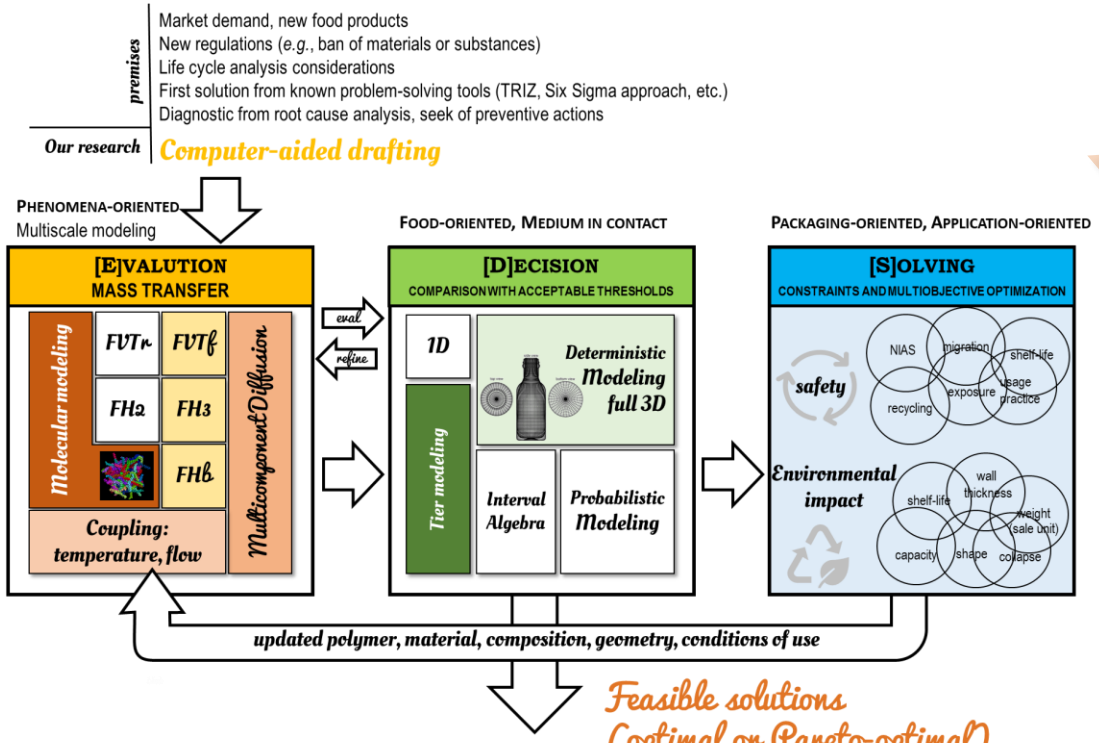


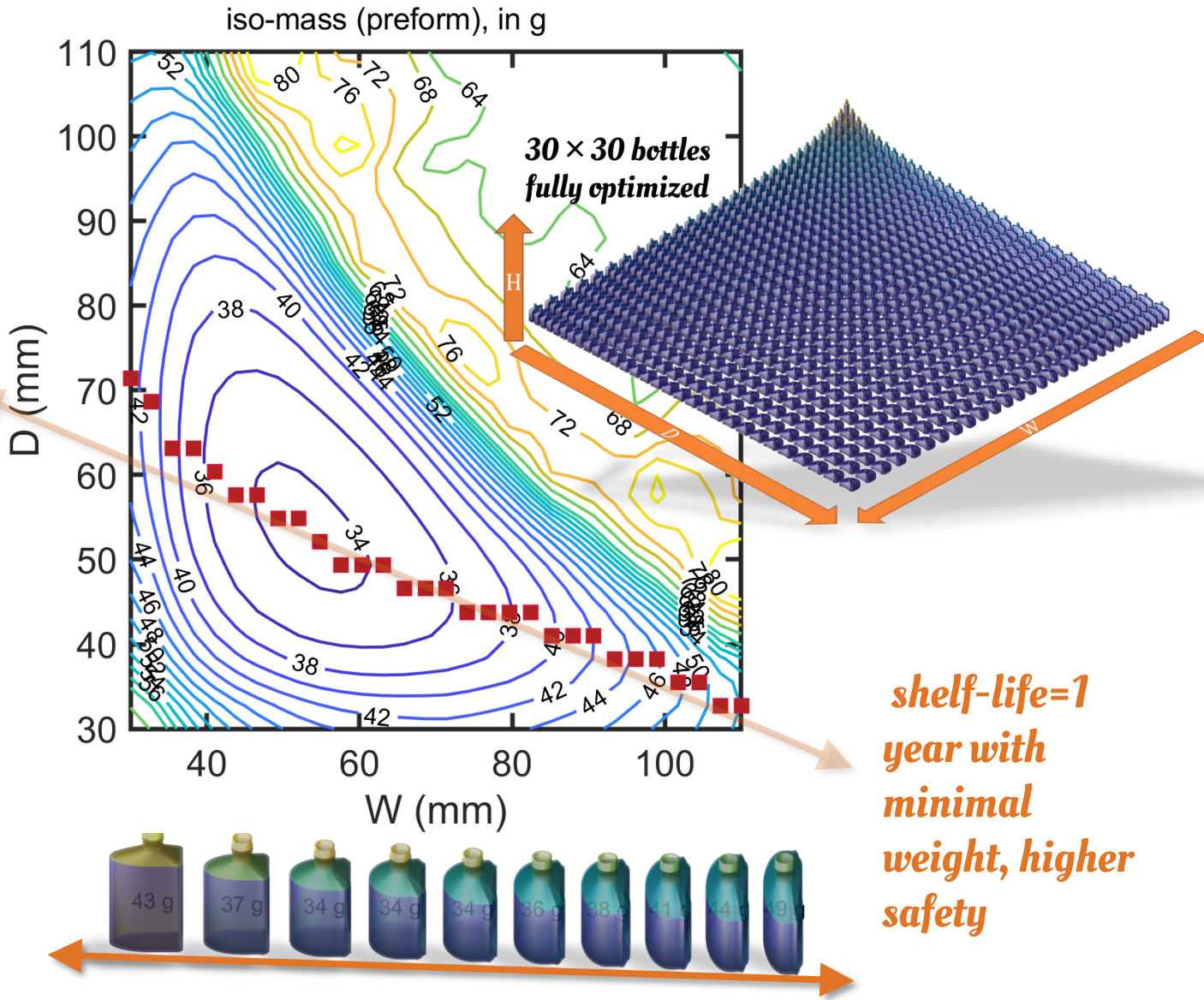
Integrated engineering



Example: redesign of PET bottle for alcoholic beverages (optimized shape, recycled content, reduced weight, improved shell-life)

3D prototype printed the same day





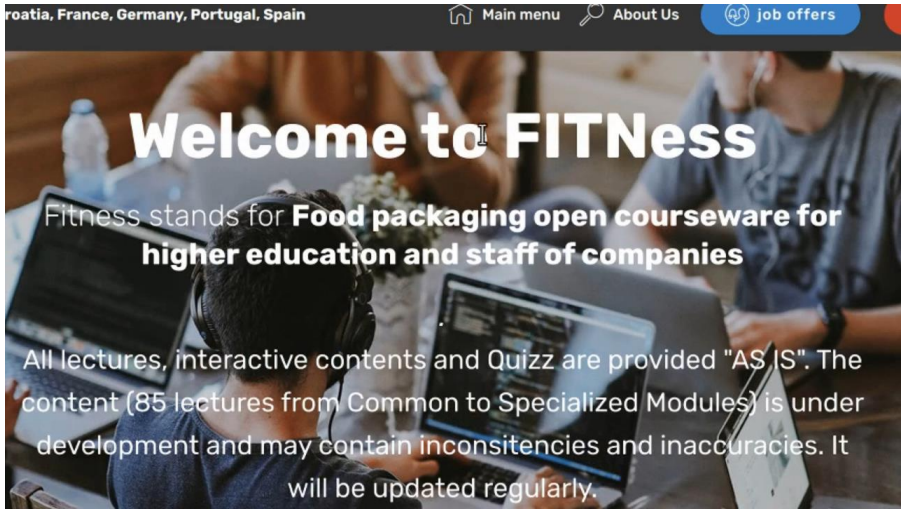
Zhu, Y., Guillemat, B., et Vitrac, O. (2019). Rational Design of Packaging: Toward Safer and Ecodesigned Food Packaging Systems. *Frontiers in Chemistry, 7(349).*

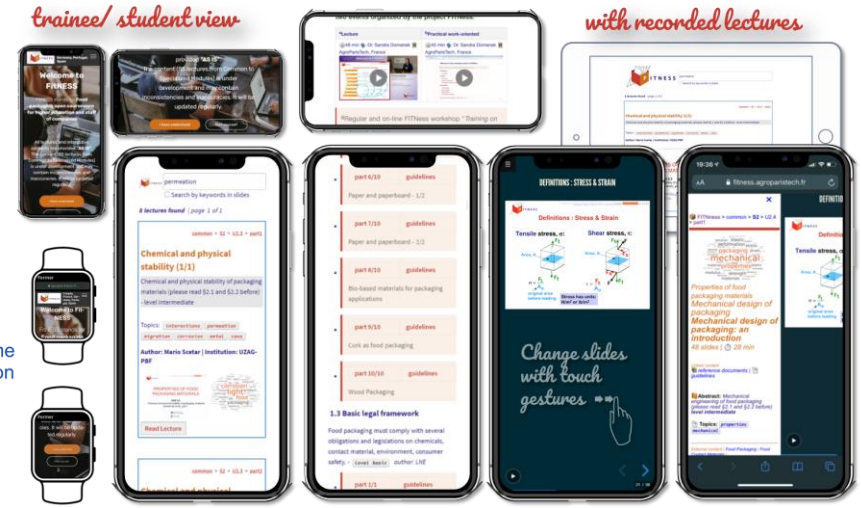
EDUCATION

Three months online curriculum on packaging design

https://fitness.agroparistech.fr/

responsible packaging use & design





BONNE PRATIQUE

Co-funded by the Erasmus+ Programme of the European Union

Conclusions & Perspectives

We are sleeping on a volcano… A wind of revolution blows, the storm is on the horizon.

Alexis de Tocqueville (1848, just prior revolutions in Europe).

Think differently

Think circular, think parsimoniously, think frugality, think bulk

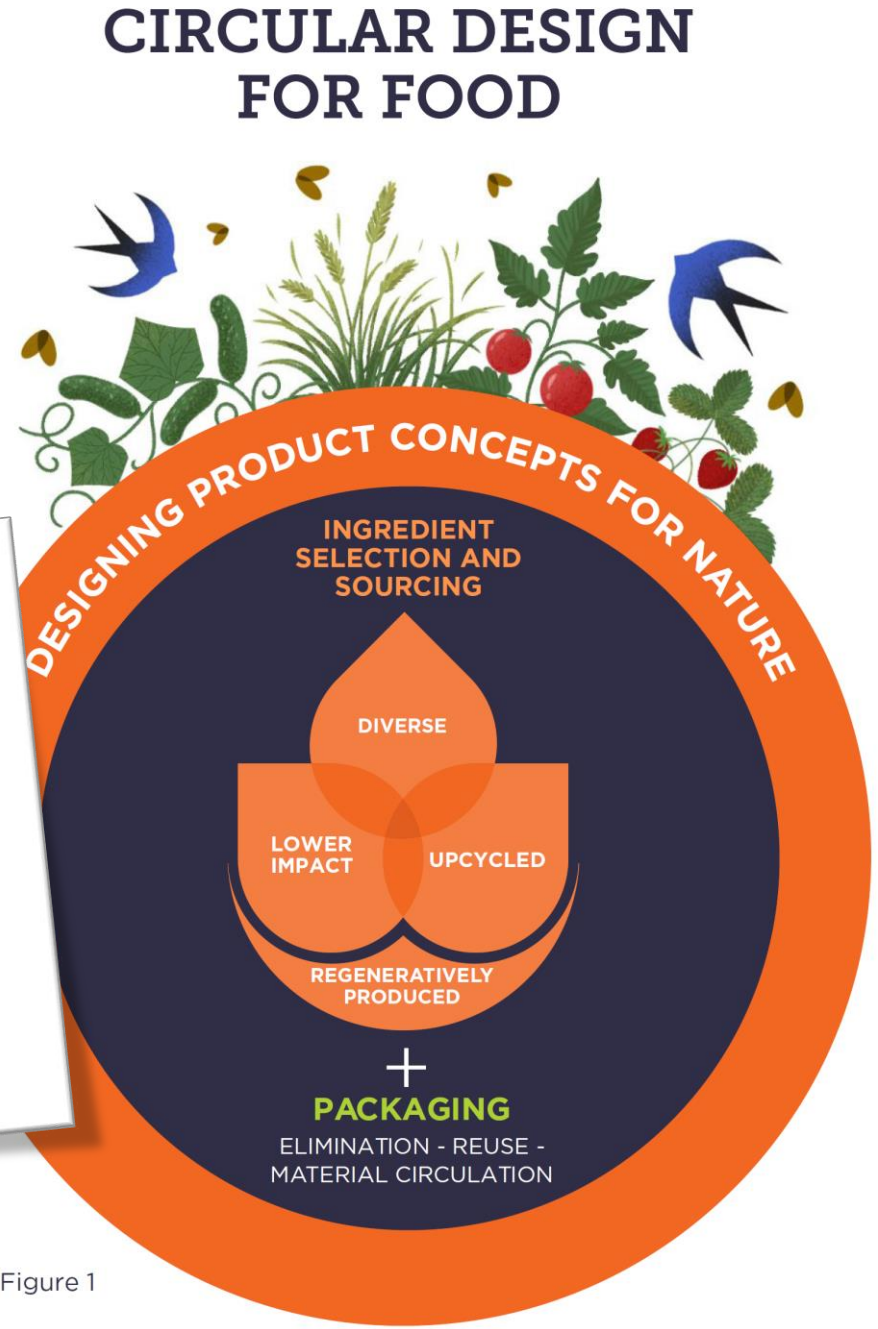
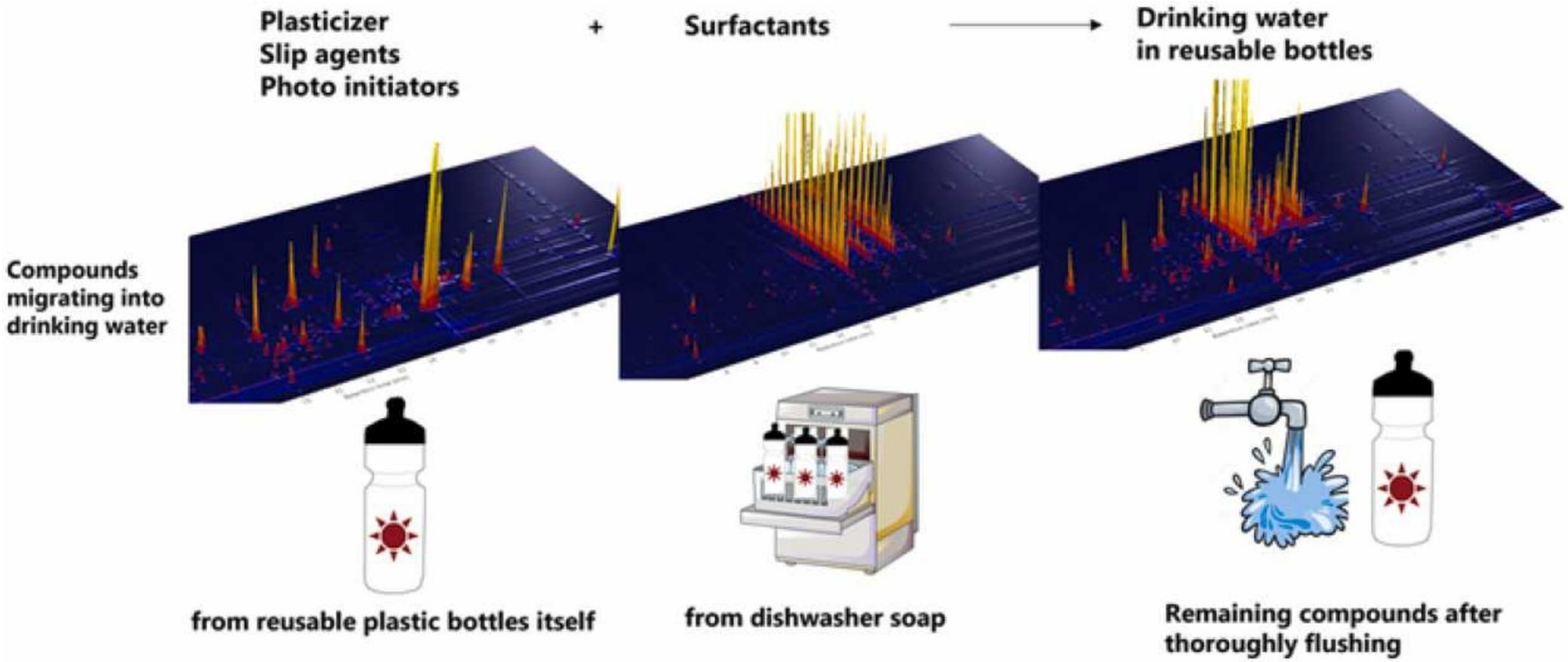
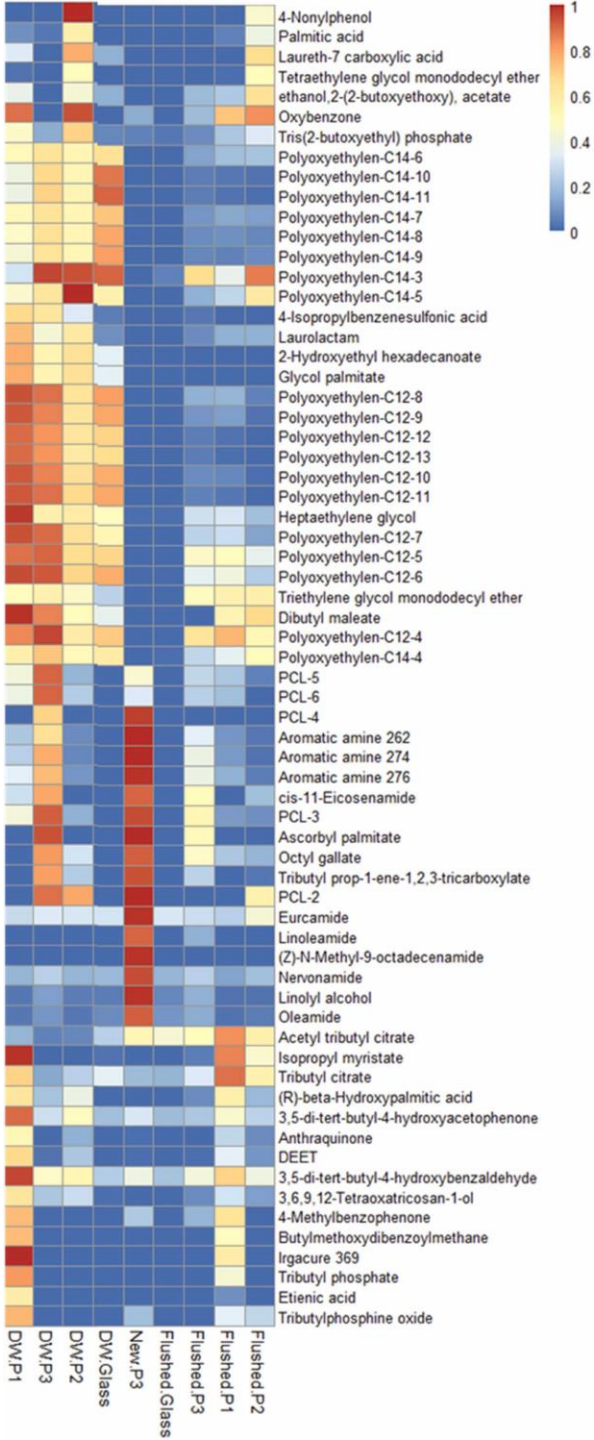


Figure 1

Think safety, always

A good idea can become a bad idea

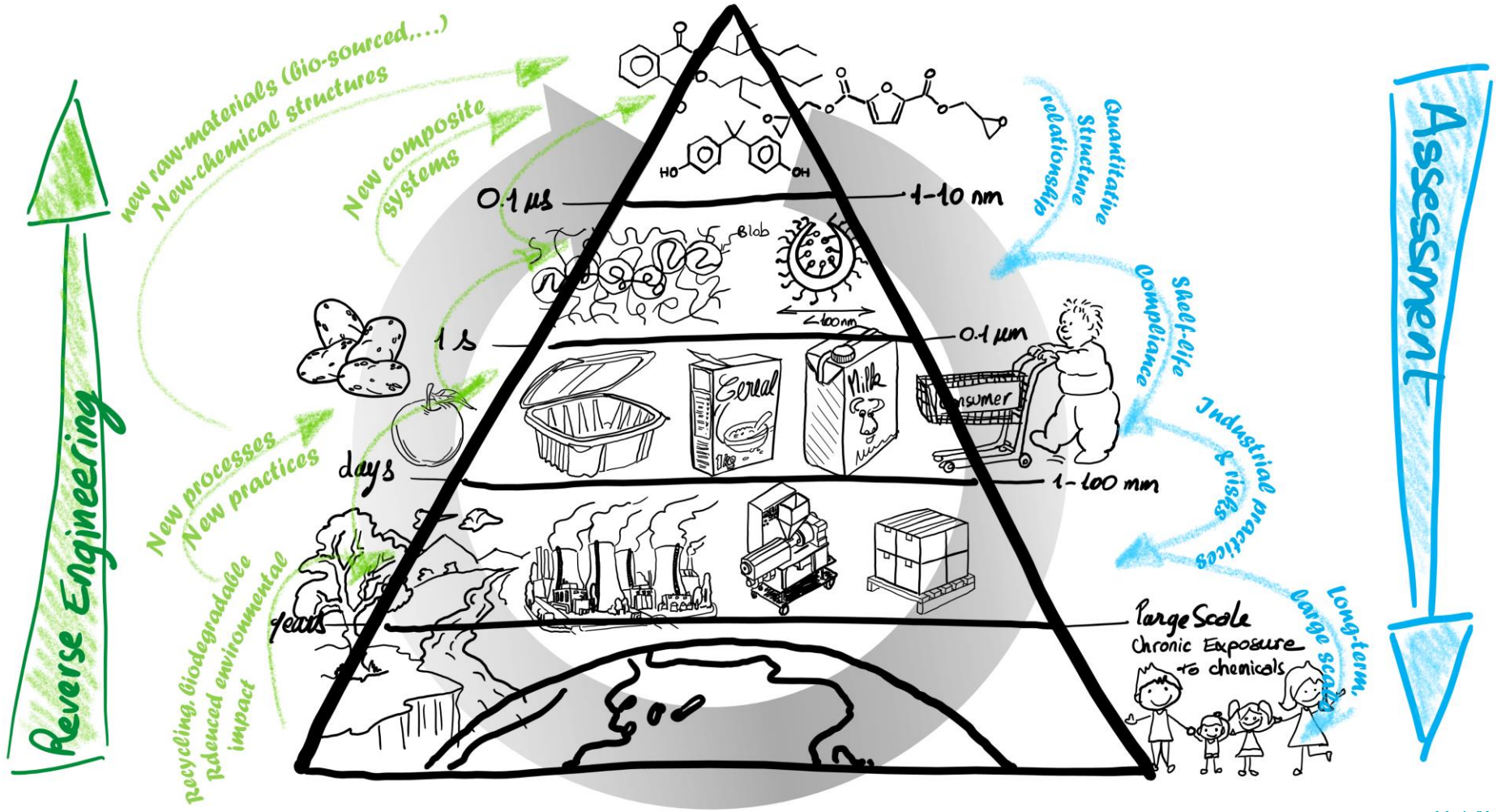




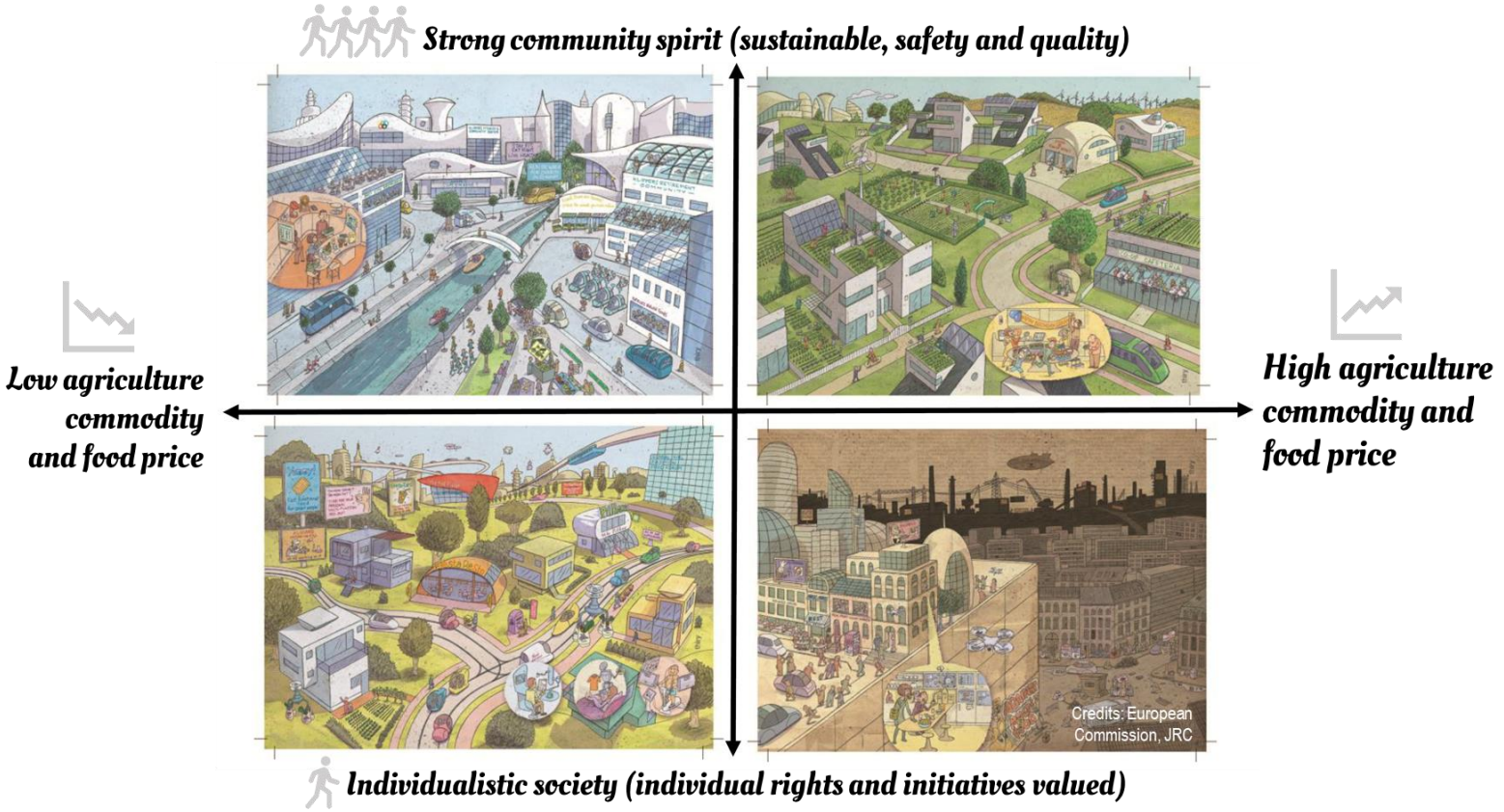
Journal of Hazardous Materials 429(5) May 2022, 128331

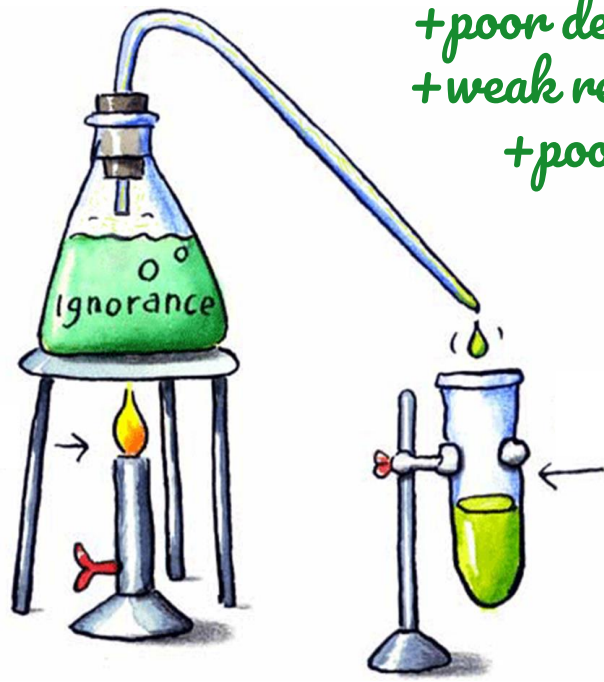
Future of packaging design = safe-by-design + ecodesign

Think
BIG
with engineering



Let's foresight modeling support public decision and let's invent our future





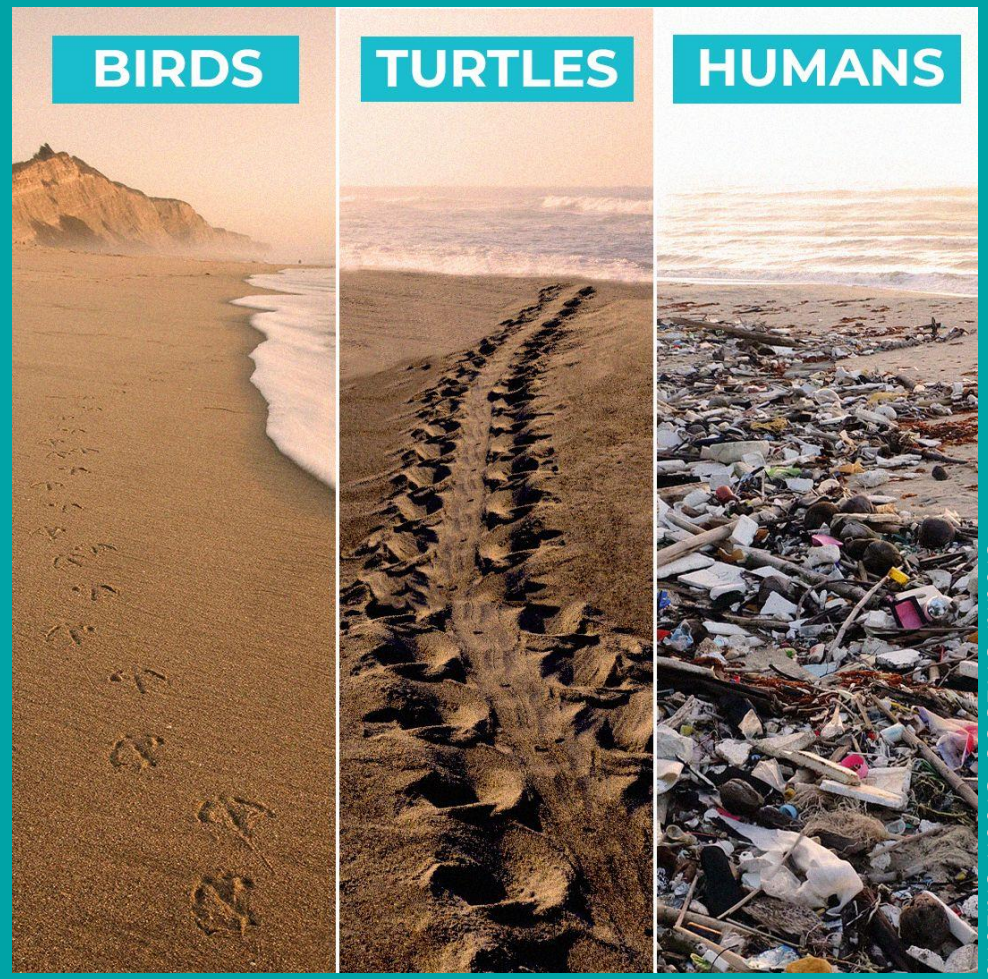
+poor design and GMP
+weak regulation rules
+poor training

=Risk of Contamination + Environmental impact

$$ignorance = \frac{IT}{WHAT\ ABOUT\ IT}$$

INRAE

Thank You For Your Attention



Credit: UNESCO Green Citizens

olivier.vitrac@agroparistech.fr

Any questions?