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Expertise scientifique collective sur les plastiques utilisés en agriculture et pour l'alimentation

Contexte, messages clés & focus sur les impacts

Muriel Mercier-Bonin



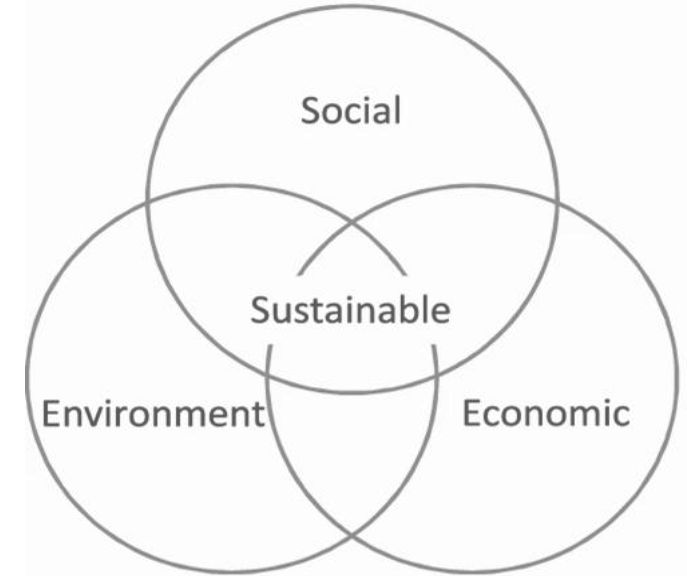
Collective scientific assessment: principles & experts

A review of the scientific literature on the sustainability of plastics used in agriculture and for food

- Analysing trade-offs between benefits and costs, including human health and environmental costs

Following four core principles

- Competence
- Plurality of disciplines and approaches
- Impartiality
- Transparency



- **A multi-disciplinary group of 33 European experts from 24 public research organisations in 8 countries** involved
- Nearly **4500 publications** (published between 2000-2023) critically analysed, of which over 90% academic publications and about 100 legislative and regulatory texts.

➤ Key messages

Key messages

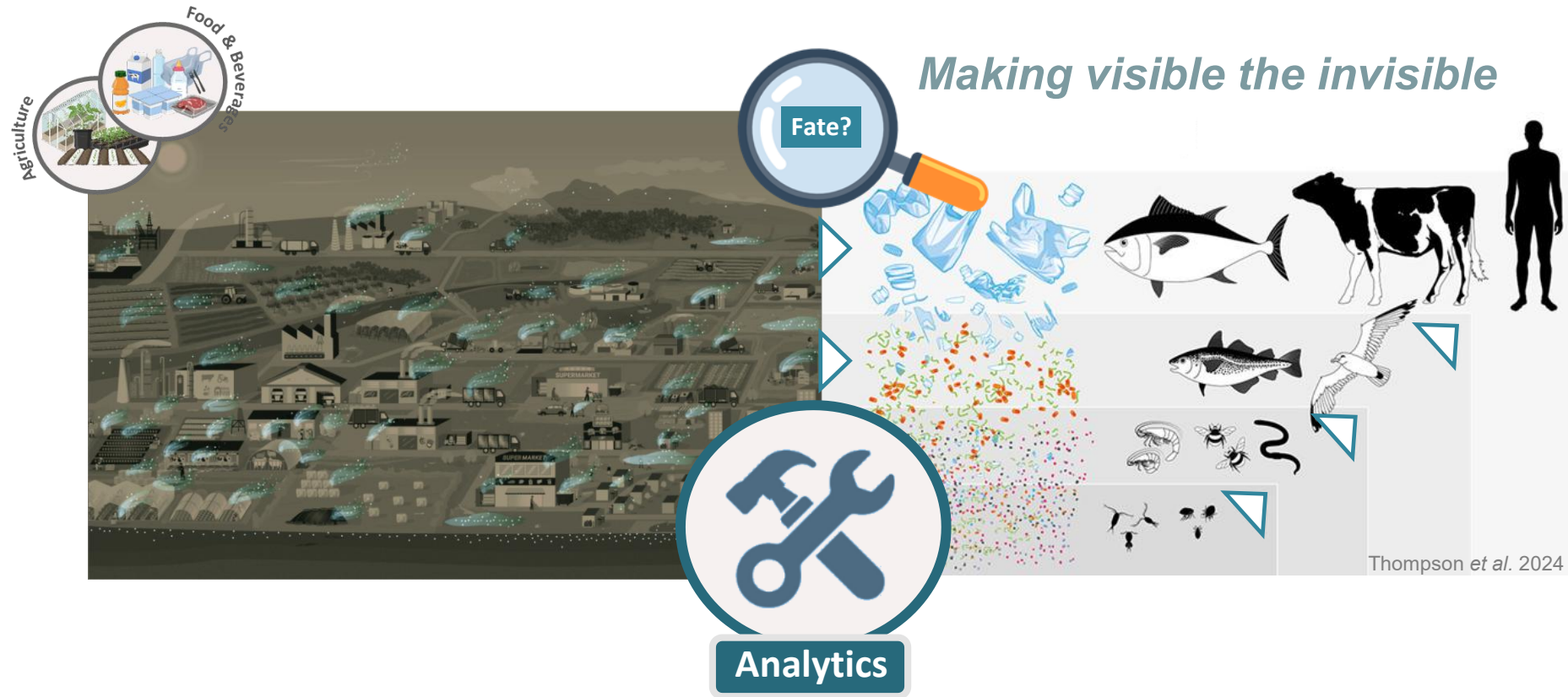
- Plastics have spread throughout food value chains
- The plasticity of plastics encourages their complexity
- Plastic waste management is difficult to monitor and implement in practice
- Plastics are ubiquitous, hazardous & have multi-scale impacts
- Is a sustainable system of plastics used in agriculture and for food possible?

Key messages

- Plastics have spread throughout food value chains
- The plasticity of plastics encourages their complexity
- Plastic waste management is difficult to monitor and implement in practice
- Plastics are ubiquitous, hazardous & have multi-scale impacts
- Is a sustainable system of plastics used in agriculture and for food possible?

- **Plastics are ubiquitous, hazardous & have multi-scale adverse impacts on living organisms, humans and continental ecosystems**

Dispersion in the environment, living organisms and along food chains



Experimental analytical methods for plastics exist but need to be improved for the wide range of matrices and plastic forms being considered

Complementary analytical methods & tools available



Direct or differential approaches

Organic molecules: GC and LC & **Trace metal elements:** ICP-OES/MS, X-ray Fluorescence, Atomic Absorption Spectroscopy

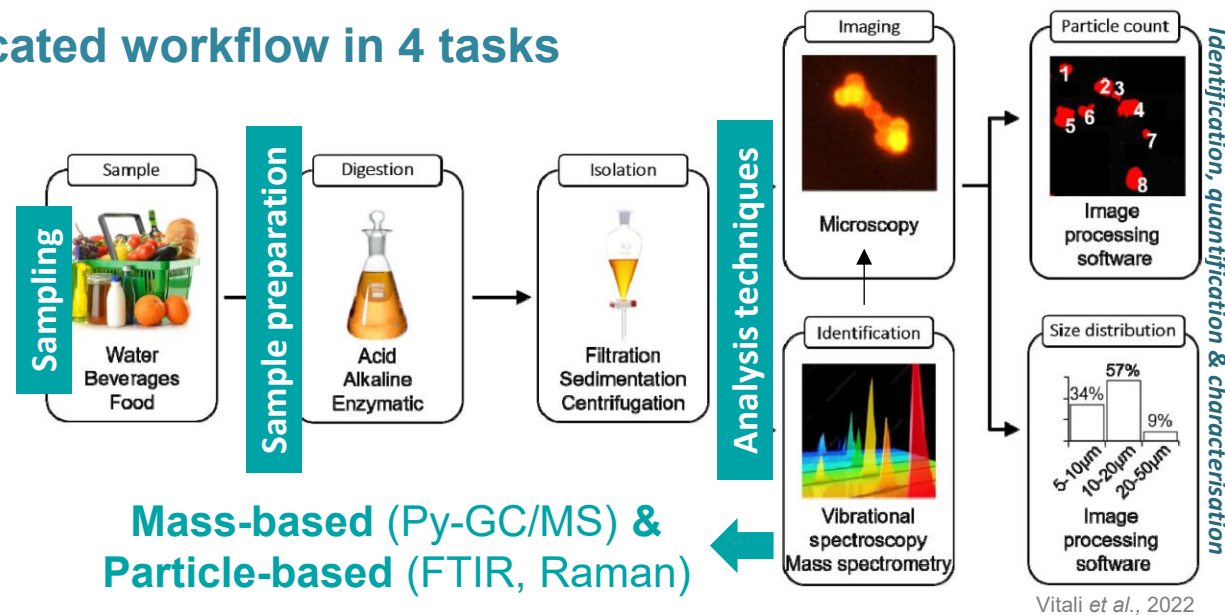
Accurate identification: HRMS (QTOF or Orbitrap)

Oligomers: LC or GC-MS for food samples, more challenging for environmental samples



Example of food
& beverages

A dedicated workflow in 4 tasks



**Mass-based (Py-GC/MS) &
Particle-based (FTIR, Raman)**

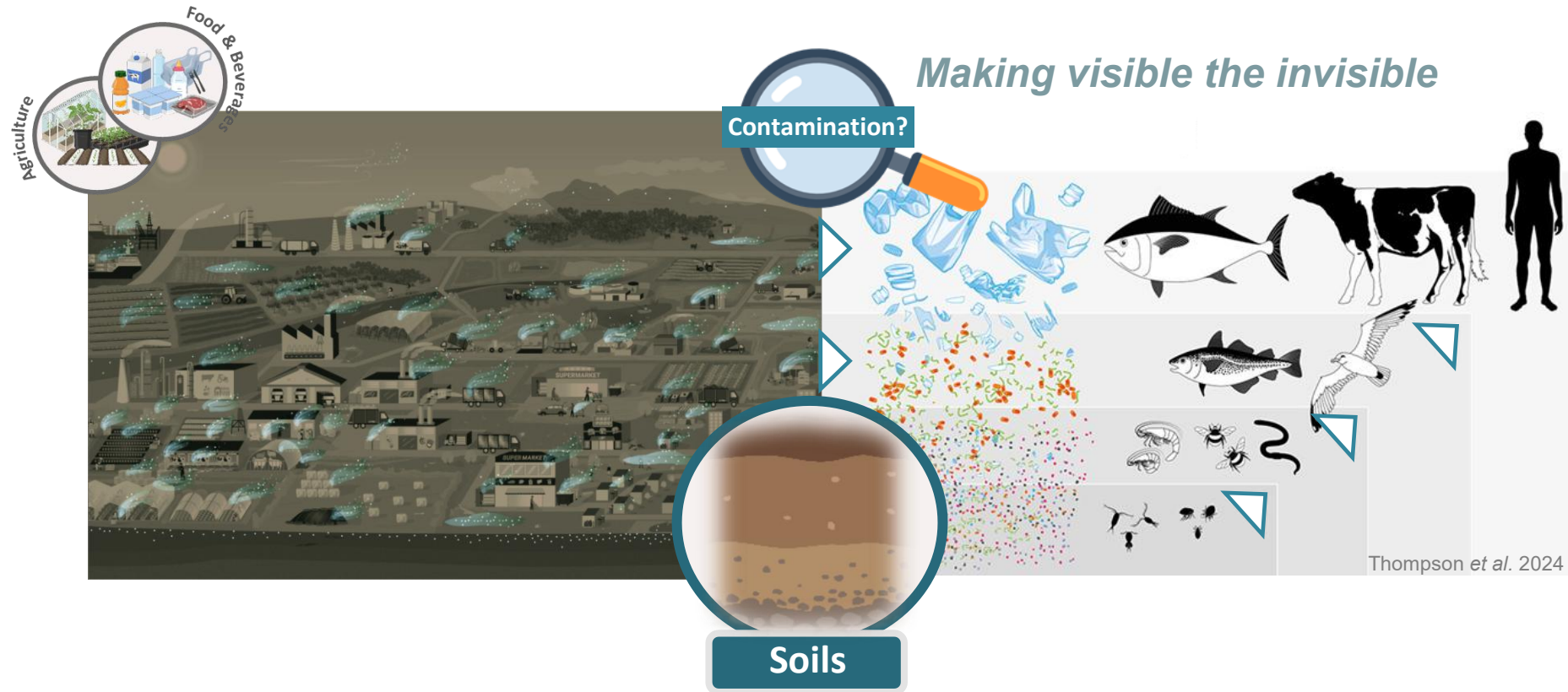
For a wide range of matrices:

- Environmental compartments (atmosphere, hydrosphere, pedosphere)
- Food & Beverages
- Living organisms

..... **Method Validation, Quality Assurance & Quality Control (QA/QC)**

➔ **Current lack of harmonisation and standardisation of methods & analytical issues** (interference with the matrix, analytical biases...)

Dispersion in the environment, living organisms and along food chains



Soil is the poor relation when it comes to studying plastic pollution in the environment, and yet...

➤ Dispersion in the environment, living organisms and along food chains: the example of soils

Soil contamination by plastics: a new area of research

Soils are contaminated by plastics

- **A wide range of sizes:** from macroplastics (MaPLs) to micro- (MPLs) and nanoplastics (NPLs)
- **A wide range of concentrations:**



Even remote areas (deserts) contaminated: $100 \text{ MPLs kg}_{\text{dw}}^{-1}$

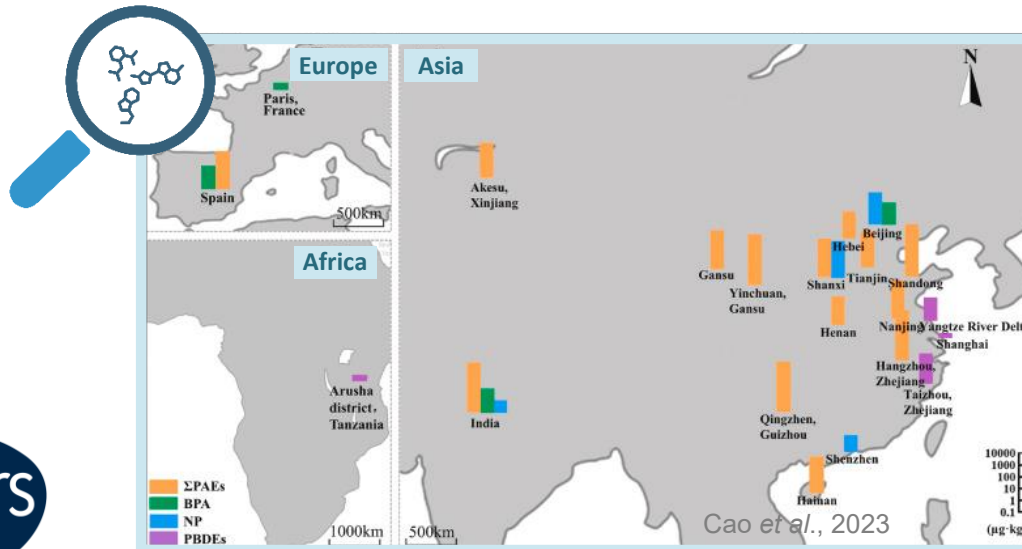
➔ **Agricultural soils: $1,000 \text{ MPLs kg}_{\text{dw}}^{-1}$**

Dense urban areas: $10,000 \text{ MPLs kg}_{\text{dw}}^{-1}$

- **Mass of MPLs in soils larger than in the oceans**

Estimate for French agricultural soils: **244 kg ha^{-1}** (Palazot *et al.* 2024)

Heavy MPL contamination



Distribution in agricultural soils

Phthalates, BPA, NP & PBDEs:
most commonly detected



BPA concentration of **$0.42 \mu\text{g kg}^{-1}$** in Paris area

Soils: diverse human sources of plastic contamination



Soil sample from Mausud and Foan island reserve (Norway) (Cyvin *et al.* 2021)



Soil in Quevillon (Normandie, France).
Former accumulation zone along the
Seine estuary



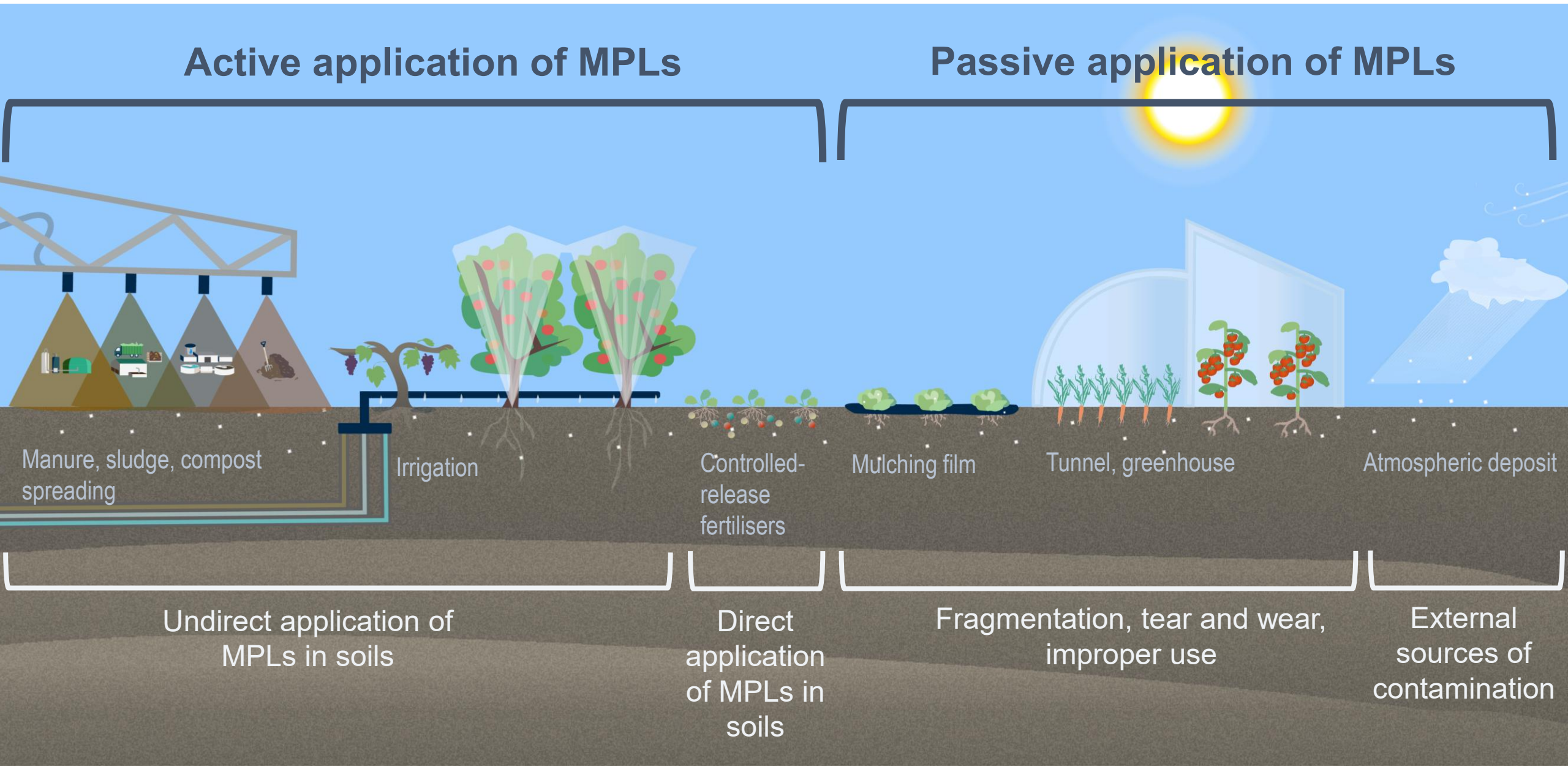
Macroplastics on agricultural soils in
France: plastic mulch in Ustaritz
(Basque Country, France)



Fragmentation into MNPLs

Fragmentation processes known **BUT** quantification of fragmentation still an open question

Agricultural soils: diverse human sources of MPL contamination



Most at-risk contamination sources linked to agriculture



Capsule-suspension
plant production
products, coated seeds
& polymer coated
encapsulated fertilisers



Bale knitted nets &
silage nets



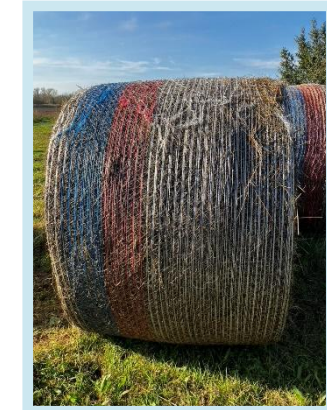
Containers of pesticides



Bale wrap films



Mulching films



Bale netwraps &
press films

Quantification of contamination sources: an attempt

B. Tassin - CSA Extended Report

Origin of contamination	Order of magnitude of contamination (MPLs·ha ⁻¹ ·yr ⁻¹)	
	Minimum	Maximum
Irrigation (wastewater)	millions	thousands of millions
Atmospheric deposits	hundreds of millions	thousands of millions
Sludge application	tens of millions	hundreds of millions
Manure application	millions	tens of millions

Based on the sources most frequently cited in the literature



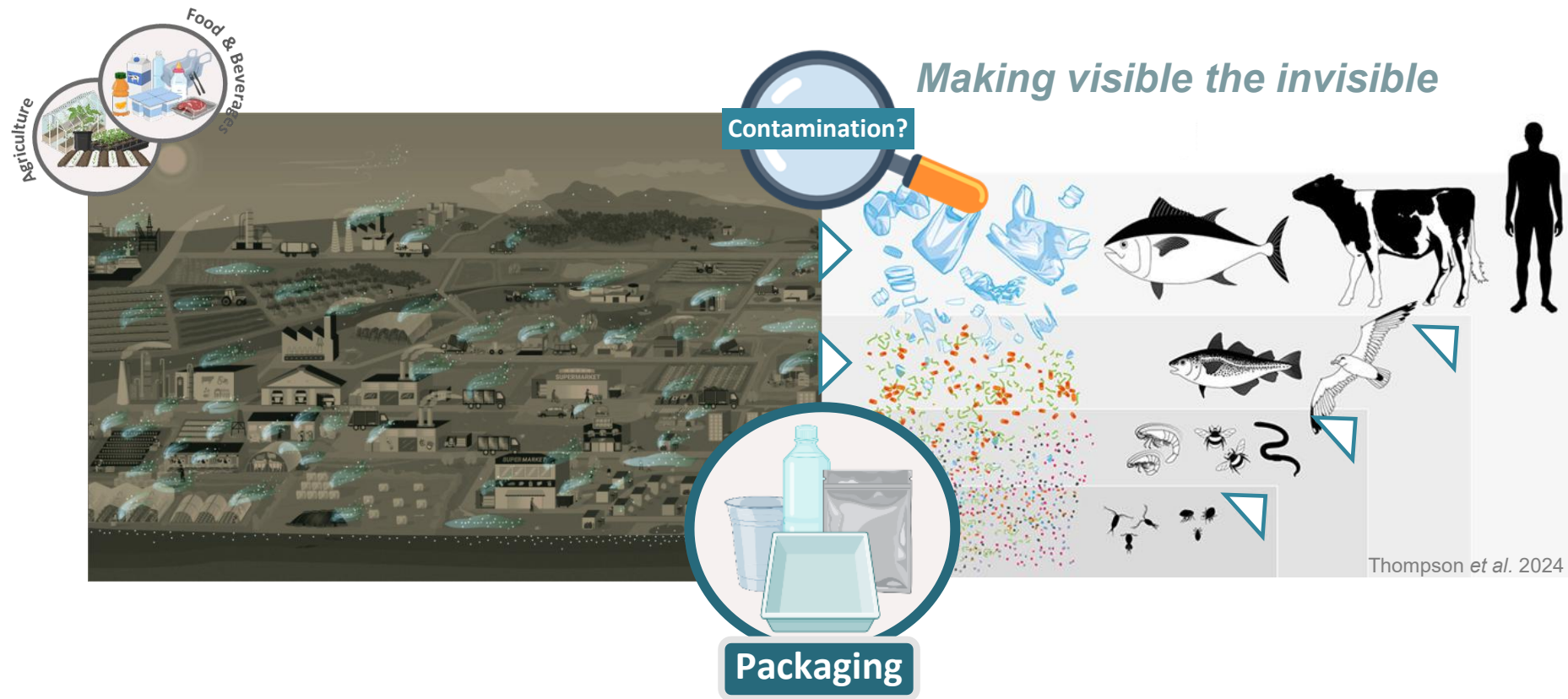
Numerous and cumulative uncertainties

Equivalent contamination sources?



Quantification of fluxes between compartments

Dispersion in the environment, living organisms and along food chains



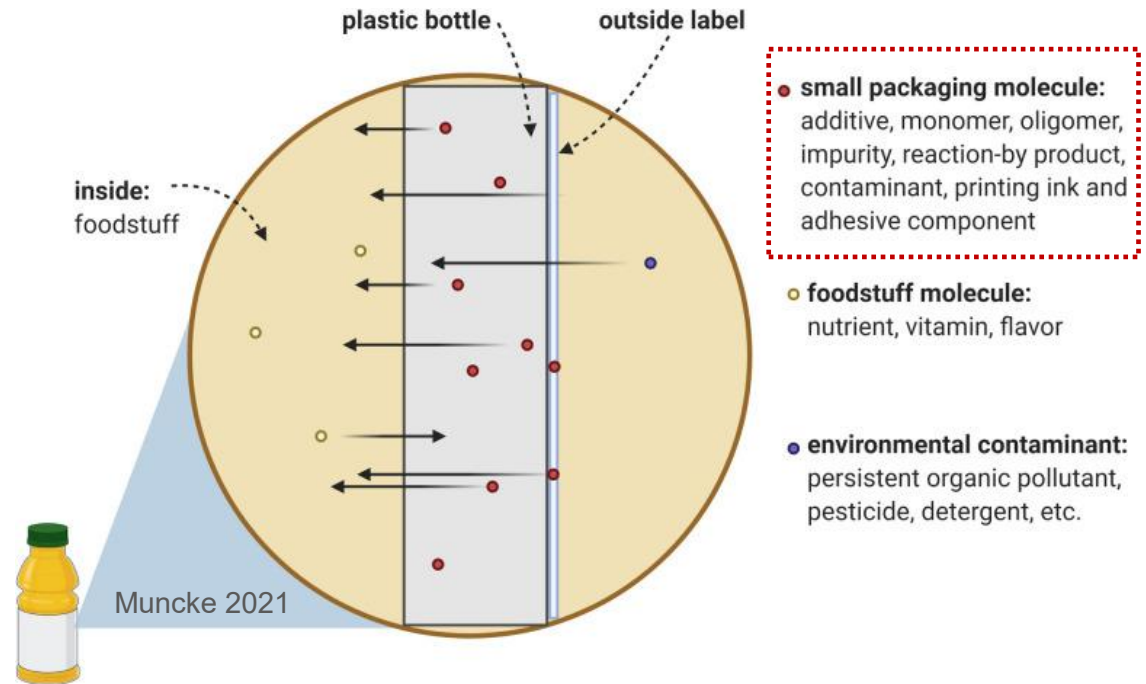
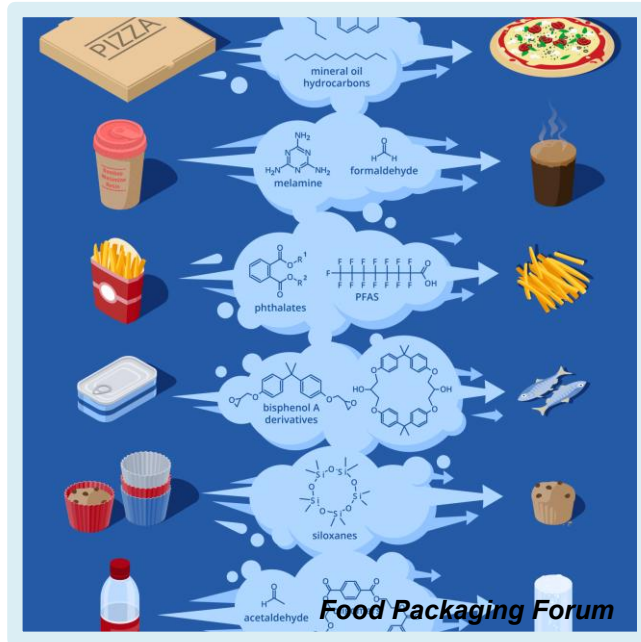
Food and drinks intended for human consumption are contaminated by plastics

Migration of chemical substances



Food contact materials (FCMs): chemical substances > 10,000

Positive List of Food Contact Substances (EU) & Databases e.g. Migrating and Extractable Food Contact Chemicals (FCCmigex)

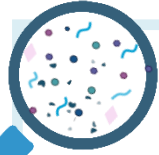


Food packaging and other food contact articles: migration of chemicals into food and drinks

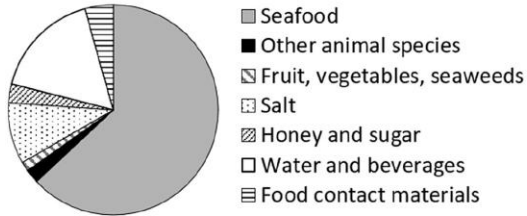
- **Food packaging:** phthalates, antioxidants (BHT, BHA), oligomers and bisphenols
- **Tableware and kitchen utensils:** melamine derivatives and formaldehyde - role of heating or contact with acidic/fatty foods

Mainly **conventional petroleum-based plastics** compared to bio-based plastics (88% vs 12%)

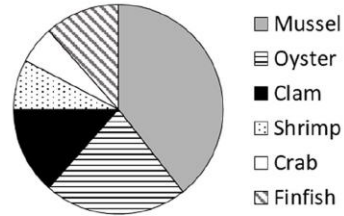
MNPLs and possibly oligomer submicrometre particles



Food, water and beverages



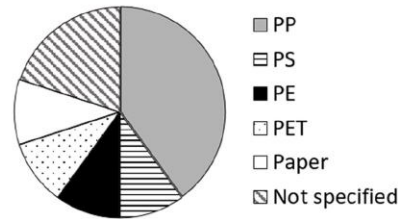
Seafood



Water and beverages



Food contact materials



Vitali *et al.*, 2023

MPL contamination in drinking water:

- Highly variable: 0 to 5.42E+07 MPLs/L
- Water sources, geographical locations, quantification methods, inadequate analytical procedures

Potential sources of contamination:

- Food chain, environment, airborne particles
- Practices and processing, transport, storage,
- Food preparation (cooking methods, choice of kitchen utensils)

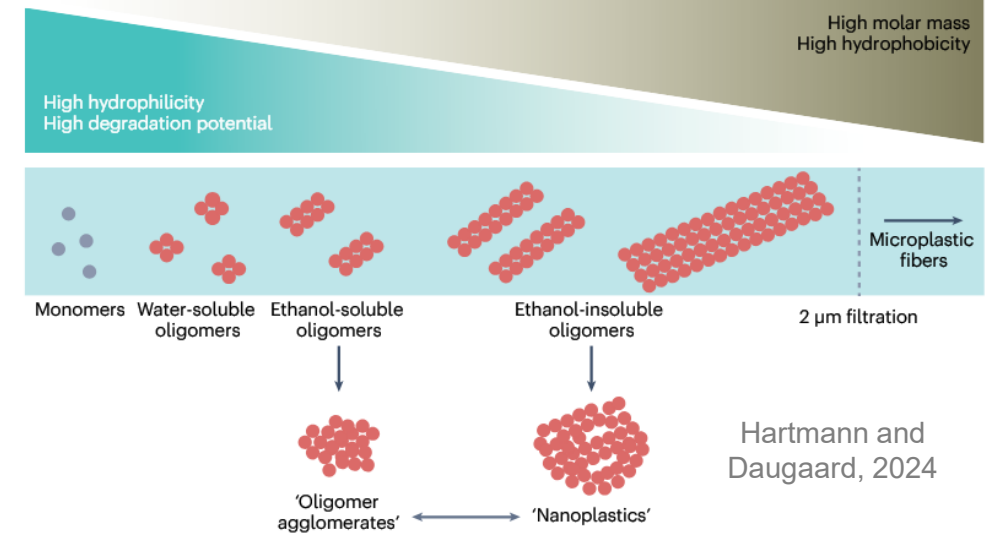
Release of MNPLs from packaging materials:

Mechanical stress (e.g. opening/closing of bottle caps) or thermal stress (heat, freezing)

Emerging problem with oligomer aggregates:

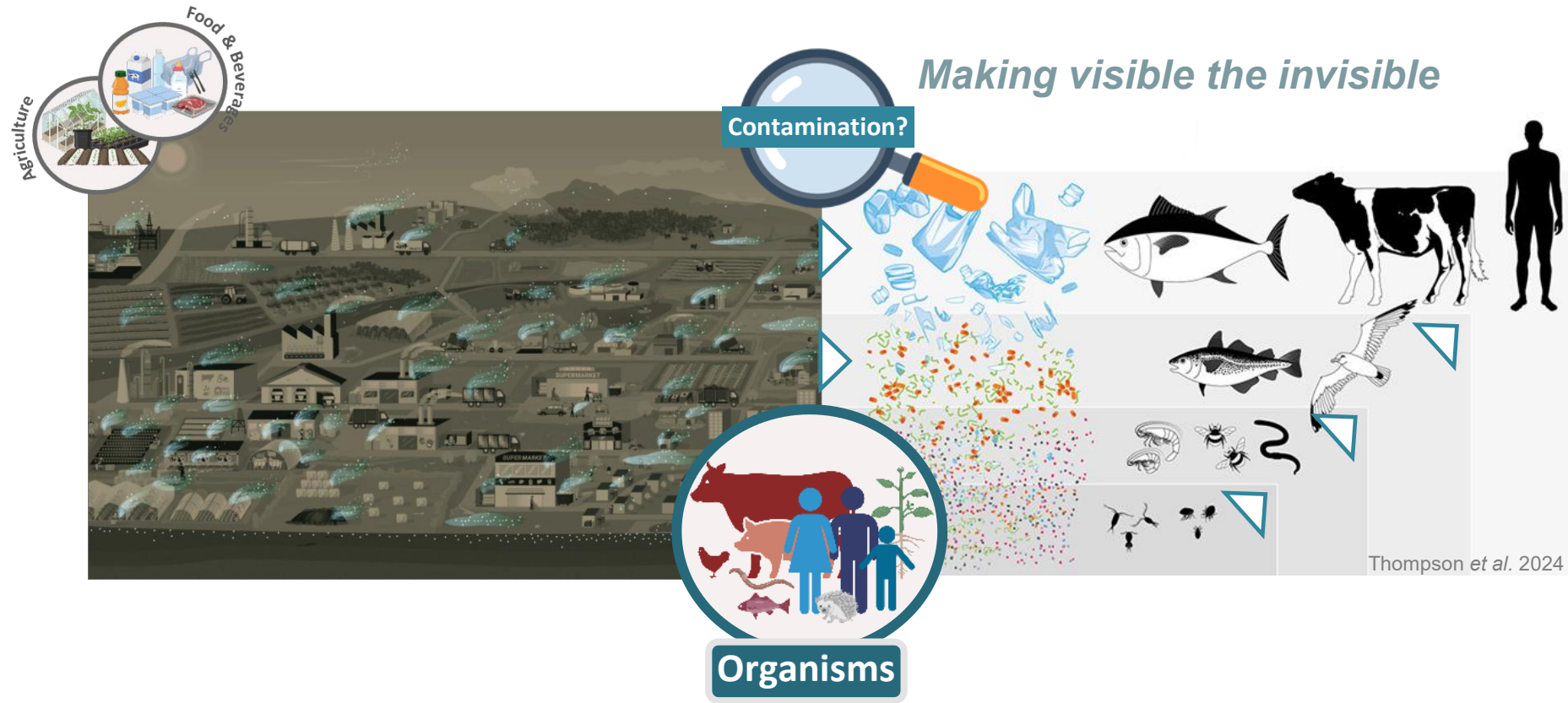
Chemical identification, distinction with NPLs (e.g. for PE and PET: ethanol pre-treatment)

Exploring the continuum between NPLs and oligomers



Hartmann and Daugaard, 2024

Dispersion in the environment, living organisms and along food chains



Biota are contaminated by plastics in their various forms and contribute to their dispersion

Contamination of living organisms by plastics



Ubiquitous contamination by plastics depending on e.g. their size
Mobile organisms: contribution to the long-range dispersion of MPLs following ingestion and subsequent egestion



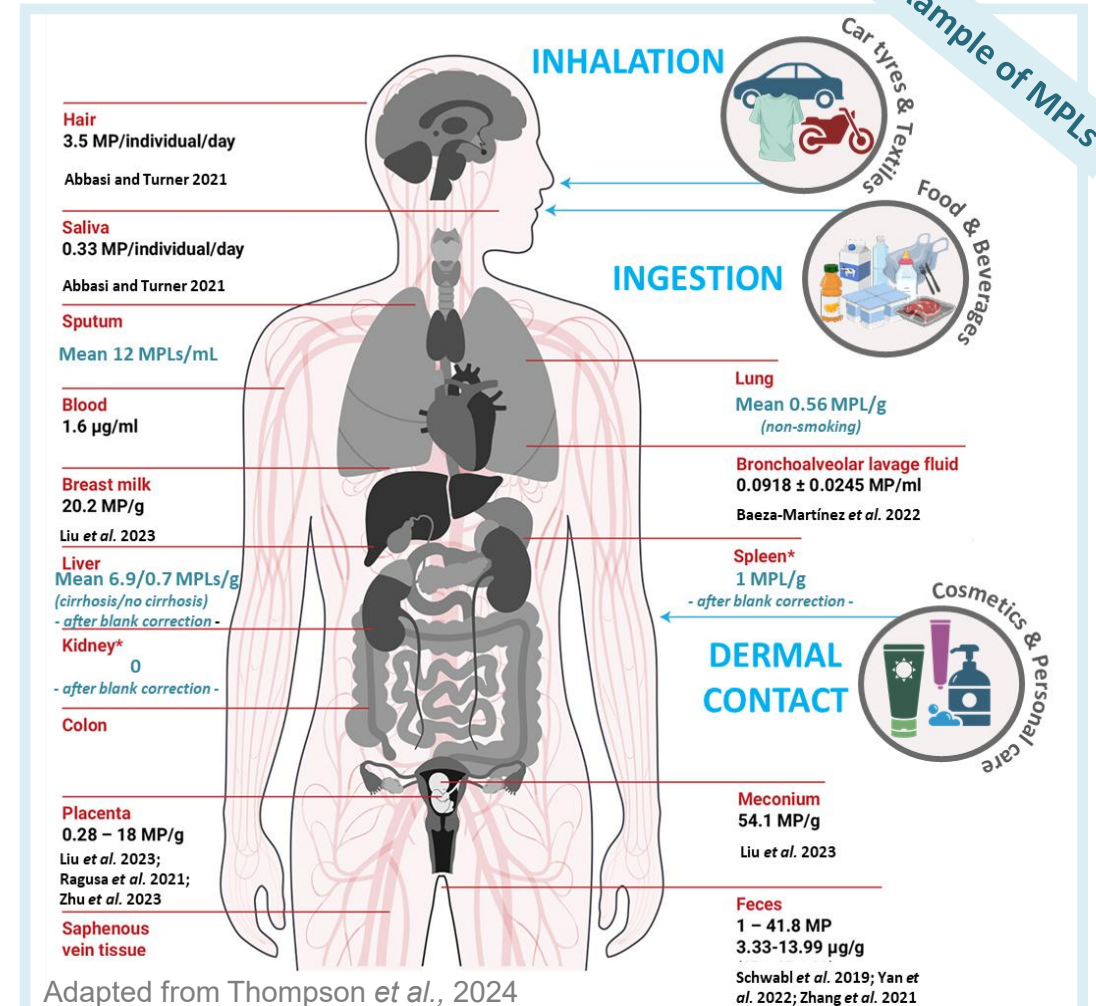
Food contact chemicals

- Presence in human samples for a total of **3601 (25%)** of the 14,402 known food contact chemicals

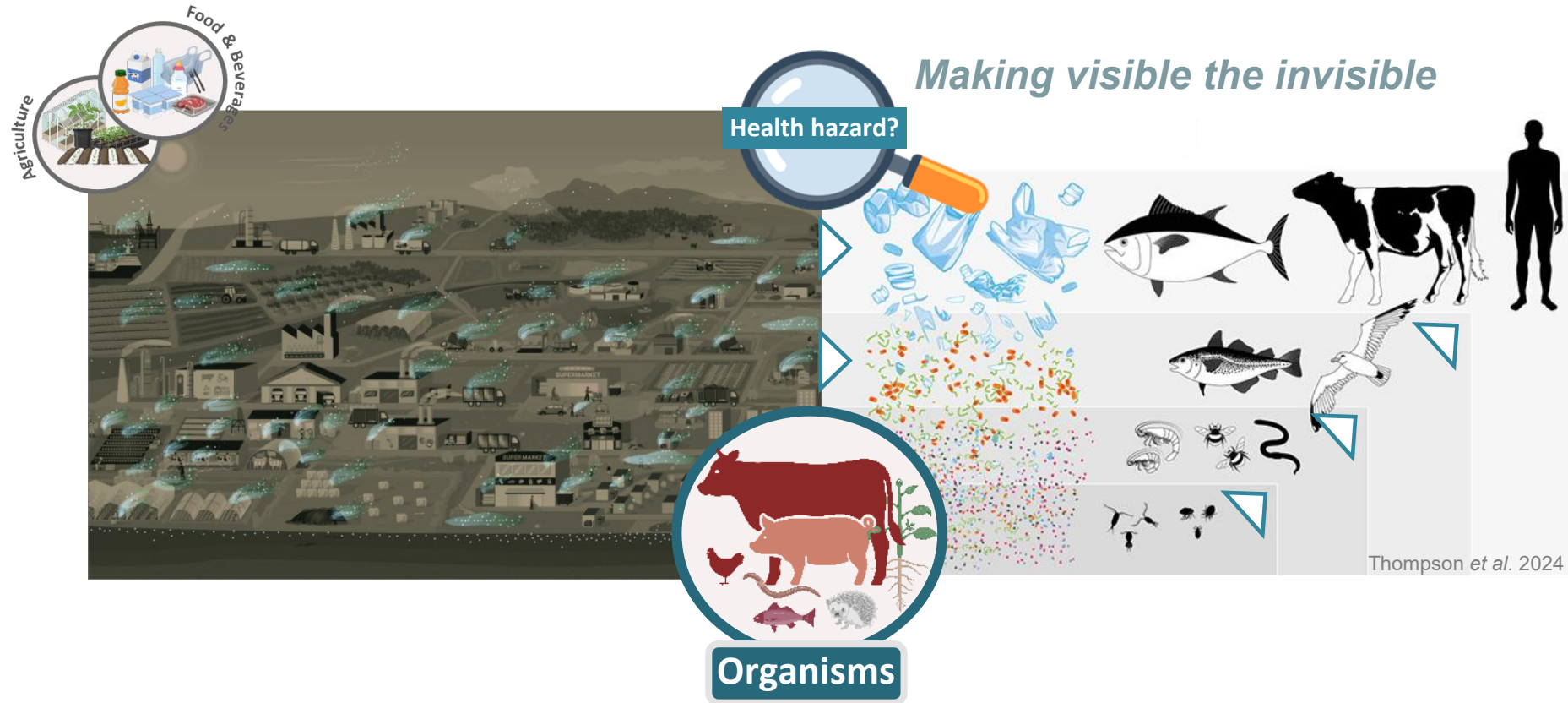


Main focus on MPLs

- Diversity of polymer types found in human samples** (petroleum origin; lack of data on bio-based and/or biodegradable plastics)
- Sometimes linked to **lifestyle habits**
- Exposure data: **no consensus yet**

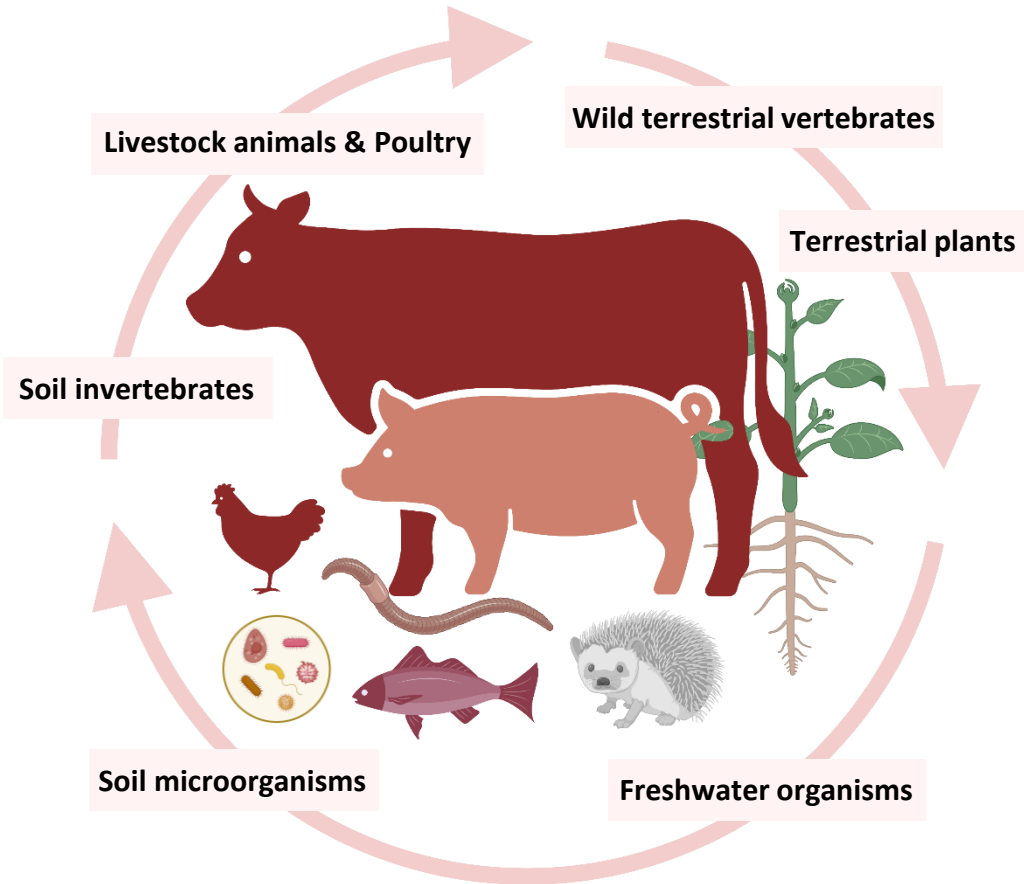


Health hazard to living organisms & Impacts on ecosystems through widespread contamination



Plastics have (eco)toxicological effects on living organisms at multiple scales

Effects of plastics on living organisms



Most well known for a limited number of chemicals

Endocrine disruptors (phthalates, bisphenols): impact on **reproduction**

Main focus on MPLs

Soil organisms: few species, effects through **soil-food web**, **plastisphere**

Wild vertebrates: few (lab-scale) studies

Livestock animals & poultry: impact on **yield, growth** and **meat quality**



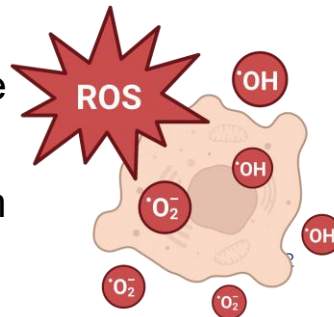
More in-depth research needed

LIMITATIONS: few types of polymers (over-representation of PS), use of monodisperse, spherical and pristine particles (commercial sources)

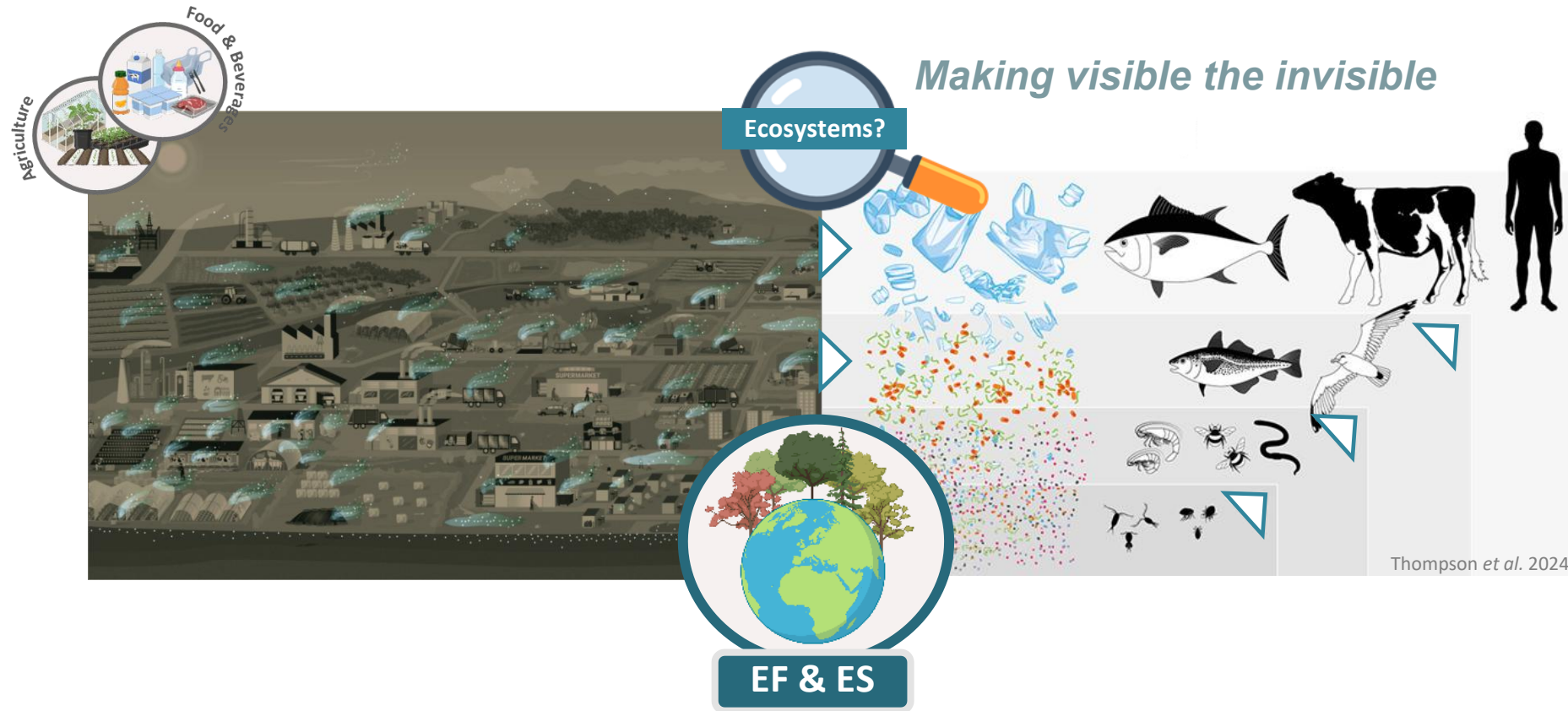
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BUT: adverse effects on behaviour, biological activity, growth, reproduction, metabolism
WITH common players (microbiota) **AND** mechanisms of action (**oxidative stress**)



Health hazard to living organisms & Impacts on ecosystems through widespread contamination



The accumulation of particulate plastics has an impact on ecosystem functioning and is likely to affect the provision of ecosystem services

Effects of plastics on ecosystem functions

Ecosystem functions	
EF1	Gas regulation
EF2	Dissipation and mitigation of contaminants and wastes in terrestrial and aquatic ecosystems
EF3	Resistance to disturbance
EF4	Water retention in soil and sediment
EF5	Water flow regulation
EF6	Albedo and reflection
EF7	Production and input of organic matter in terrestrial and aquatic ecosystems
EF8	Nutrient regulation in terrestrial and aquatic ecosystems
EF9	Formation and maintenance of soil and sediment structure
EF10	Dispersion of propagules in terrestrial and aquatic ecosystems
EF11	Provision and maintenance of biodiversity and biotic interactions in terrestrial and aquatic ecosystems
EF12	Provision and maintenance of habitats and biotopes in terrestrial and aquatic ecosystems



12 EFs considered based on a previous CSA
(Pesce et al. 2023)

Recent, still fragmentary, knowledge



More in-depth research needed

EF4, EF7 and EF9 the most well documented

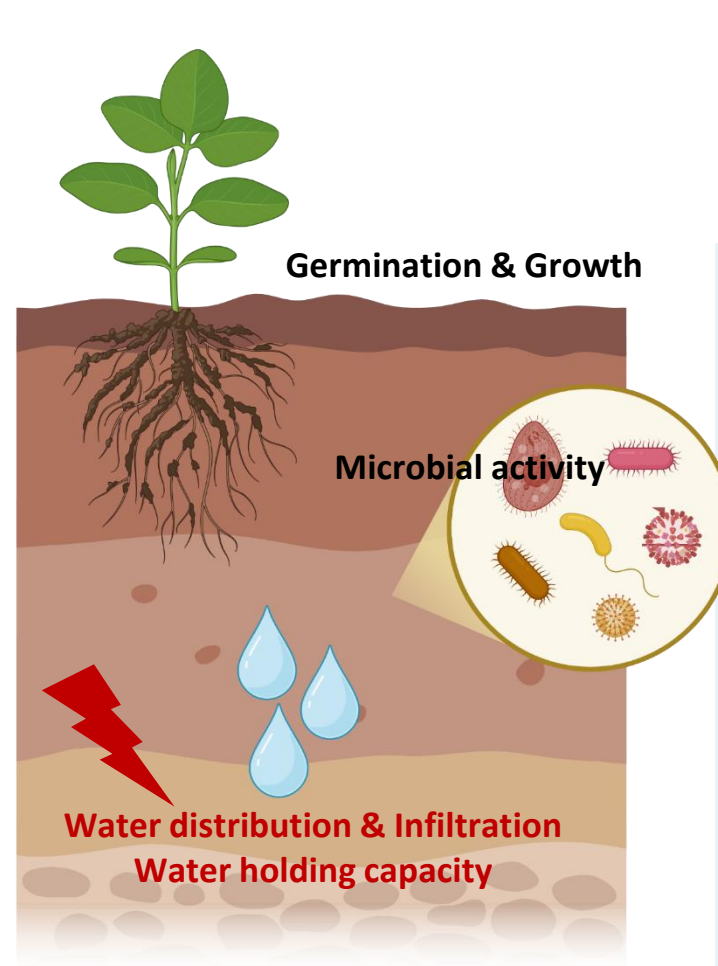


An illustration with EF4 ‘Water retention in SOIL and sediment’

Effects of plastics on ecosystem functions: example of EF4

Ecosystem functions

EF1	Gas regulation
EF2	Dissipation and mitigation of contaminants and wastes in terrestrial and aquatic ecosystems
EF3	Resistance to disturbance
EF4	Water retention in SOIL and sediment
EF5	Water flow regulation
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Presence of plastic particles in soil systems: alteration of water distribution, infiltration pathways and subsequent water holding capacity, depending on the nature of the polymer

Plastic films, and probably fibres: potential alteration of water flow in soils by affecting water infiltration and absorption, with possible implications for plant germination and growth, and reduced soil microbiological activity

Effects of plastics on ecosystem services



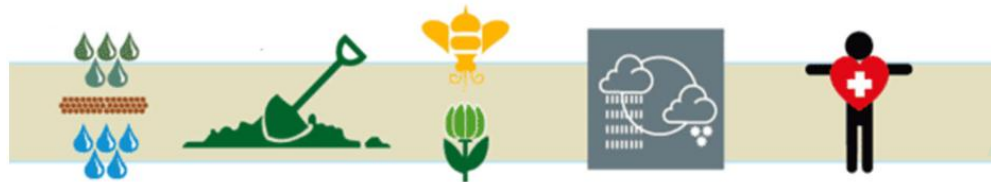
Common International Classification of Ecosystem Services

(Haines-Young and Potschin 2018)

Provision



Regulation & Maintenance



Cultural



Credit: Wilfried Sanchez

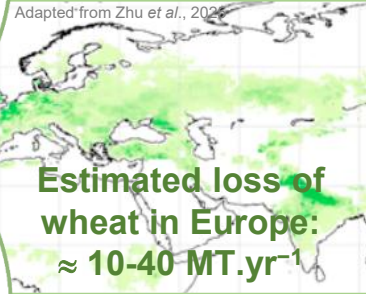
Crops

↓ biomass, productivity
(rice, wheat and maize)

Livestock & poultry

Anorexia, weight loss,
reduced growth

OM degradation
Soil alteration
Nutrient & energy
reserves
Habitats for
(micro)organisms
Disruption of the
food chain



Plastics & their likely impact on human well-being to be further investigated (e.g. other anthropogenic stressors)



In brief

Because of their many uses, plastics are now structuring both technically and culturally the food value chains, particularly downstream: their versatility has encouraged greater complexity in their formulations, making their waste management very difficult.

Their omnipresence in continental ecosystems and in the human body, and their proven impacts at all levels, therefore call into question the very possibility of making the use of plastics in agriculture and food sustainable.



Du fait de leurs usages nombreux, les plastiques structurent aujourd'hui tant techniquement que culturellement les chaînes de valeur alimentaire, en particulier à l'aval: leur versatilité a encouragé la complexification de leurs formulations ce qui contribue à compliquer très largement leur gestion à l'état de déchet.

Leur omniprésence dans tous les écosystèmes continentaux et dans le corps humain et les impacts avérés à toutes les échelles viennent donc questionner la possibilité même de rendre soutenables les usages des plastiques dans l'agriculture et l'alimentation.

Remerciements

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Illustrations de couverture : ©SAYPE photographies des œuvres d'art éphémères La grande vague (2024) et Trash (2023), peinture éco-responsable sur herbe

Pour en savoir plus :

- <https://eng-esco-plastiques-agri-alim.colloque.inrae.fr/> (vidéo du colloque de restitution & diaporama disponibles)
- <https://www.inrae.fr/actualites/expertise-plastiques-utilises-agriculture-et-alimentation>
- <https://www.cnrs.fr/fr/nos-recherches/expertise-scientifique-collective/plastiques-utilises-en-agriculture-et-pour-l'alimentation-inrae-cnrs>