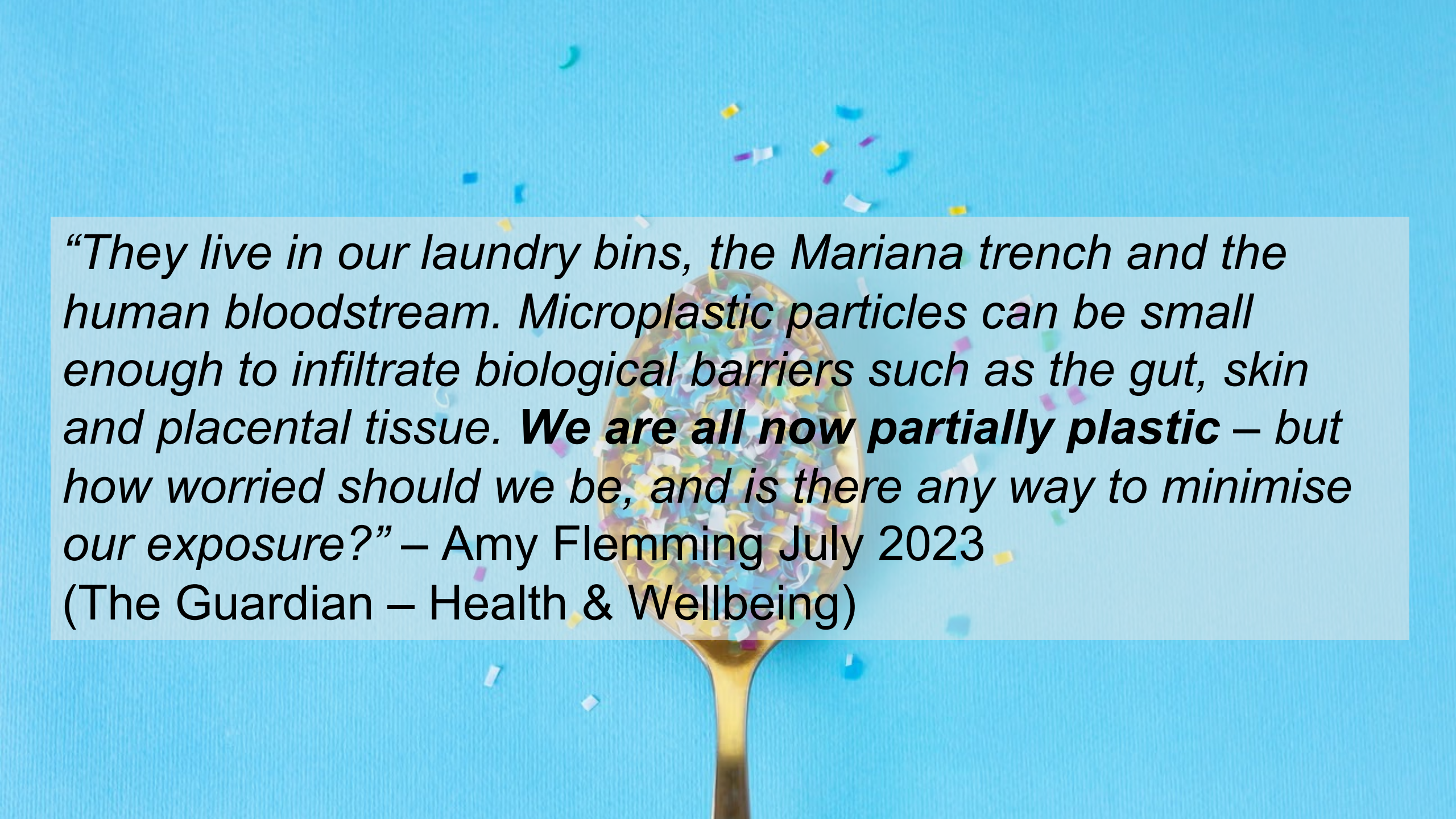
Microplastics, Public Health Myth or Menace

Ian Mudway

Legacies of Toxic Wast



“They live in our laundry bins, the Mariana trench and the human bloodstream. Microplastic particles can be small enough to infiltrate biological barriers such as the gut, skin and placental tissue. ***We are all now partially plastic*** *– but how worried should we be, and is there any way to minimise our exposure?”* – Amy Flemming July 2023
(The Guardian – Health & Wellbeing)

- ~5 Bt of plastic waste released to landfill or the environment in 2015 (Geyer et al., 2017);
- ‘…solid synthetic polymeric particles of no more than 5 mm in their longest dimension and which may contain additives or other substances.’ (European Commission, 2019)
- Photochemically and mechanically degrades to microplastic.

Lost at Sea: Where Is All the Plastic?

Richard C. Thompson,[1]* Ylva Olsen,[1] Richard P. Mitchell,[1] Anthony Davis,[1] Steven J. Rowland,[1] Anthony W. G. John,[2] Daniel McGonig

*To whom correspondence should be addressed. E-mail: rcthompson@plymouth.ac.uk

Millions of metric tons of plastic are produc annually. Countless large items of plastic deb are accumulating in marine habitats worldw and may persist for centuries (*1–4*). Here show that microscopic plastic fragments and bers (Fig. 1A) are also widespread in the ocea and have accumulated in the pelagic zone a sedimentary habitats. The fragments appear have resulted from degradation of larger iter Plastics of this size are ingested by marine orga isms, but the environmental consequences of this contamination are still unknown.

Over the past 40 years, large items of plastic debris have frequently been recorded in habitats from the poles to the equator (*1–4*). Smaller fragments, probably also plastic, have been reported (*5*) but have received far less attention. Most plastics are resistant to biodegradation, but will break down gradually through mechanical action (*6*). Many "biodegradable" plastics are composites with materials such as starch that biodegrade, leaving behind numerous, nondegradable, plastic fragments (*6*). Some cleaning agents also contain abrasive plastic fragments (*2*). Hence, there is considerable potential for large-scale accumulation of microscopic plastic debris.

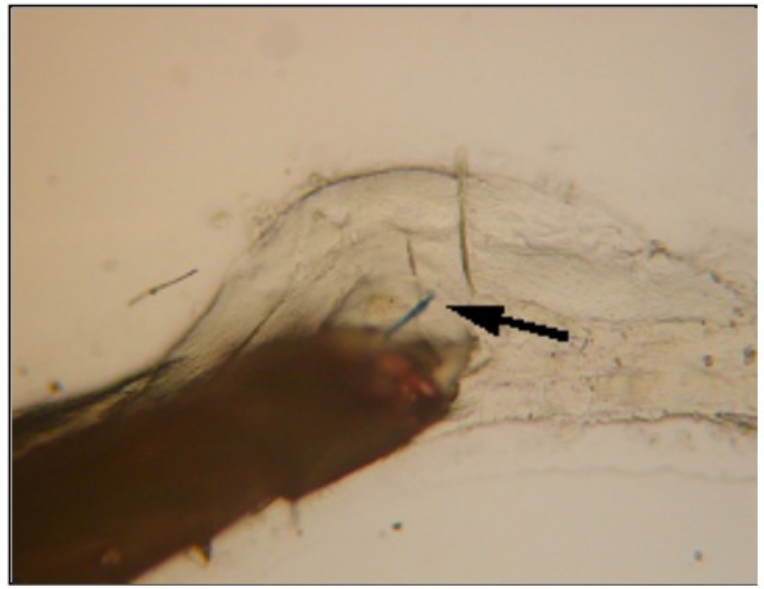
To quantify the abundance of microplastics, we collected sediment from beaches and from estuarine and subtidal sediments around Plymouth, UK (Fig. 1B). Less dense particles were separated by flotation. Those that differed in appearance to natural particulate material (Fig. 1A) were removed and identified with Fourier Transform infrared (FT-IR) spectroscopy (*7*). Some were of natural origin and others could not be identified, but about one third were synthetic polymers (Fig. 1C). These polymers were present in most samples (23 out of 30), but were significantly more abundant in subtidal sediment (Fig. 1D). Nine polymers were conclusively identified: acrylic, alkyd, poly (ethylene:propylene), polyamide (nylon), polyester, polyethylene, polymethylacrylate, polypropylene, and polyvinyl-alcohol. These have a wide range of uses, including clothing, packag-

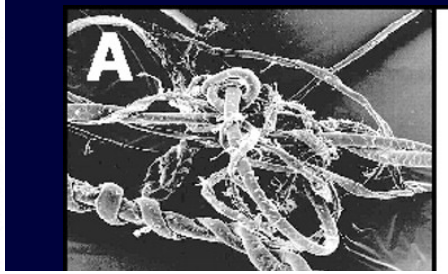
land (850 km) (*7*) (Fig. 1B). We found plastic archived among the plankton in samples back to the 1960s, but with a significant increase in abundance over time (Fig. 1E). We found similar types of polymer in the water column as in sediments, suggesting that polymer density was not a major factor influencing distribution.

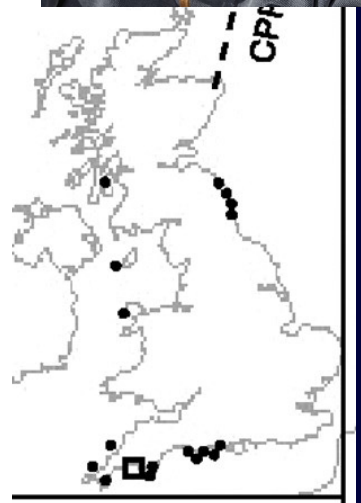
It was only possible to quantify fragments that

14.42, $P < 0.05$). Approximate global production of synthetic fibers is overlain for comparison. Microplastics were also less abundant along oceanic route CPR 1 than along CPR 2 ($F_{1,24} = 5.18$, $P < 0.05$).

Hardy Foundation for Ocean Science, Plymouth, PL1 2PB, UK. [3]University of Southampton, SO17 1BJ, UK.







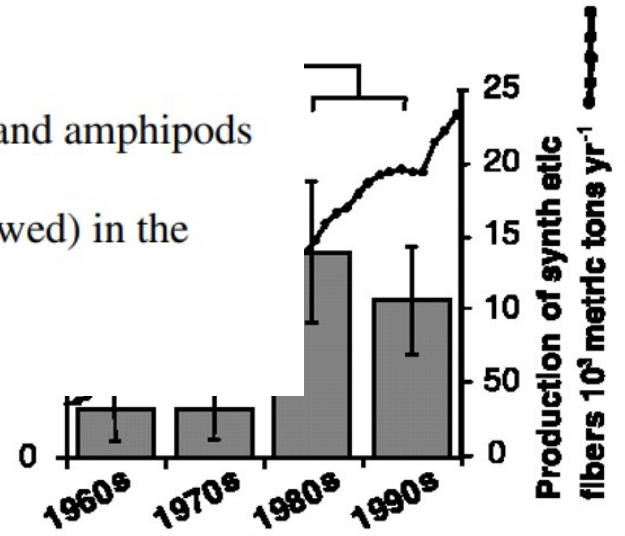
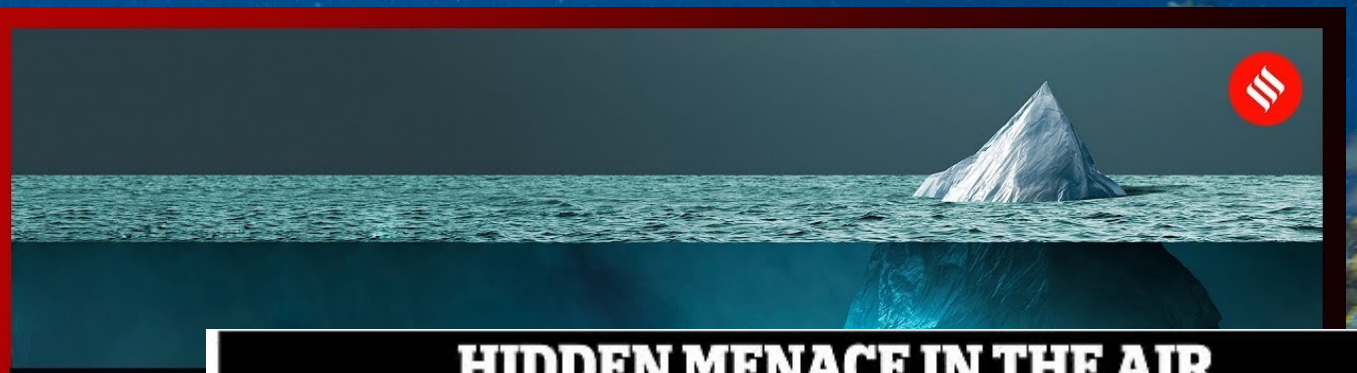


Fig. S1. Microscopic plastics were ingested by polychaete worms, barnacles and amphipods during laboratory trials. Here a microscopic plastic fragment is pictured (arrowed) in the intestinal tract of the amphipod (*Orchestia gammarellus*).

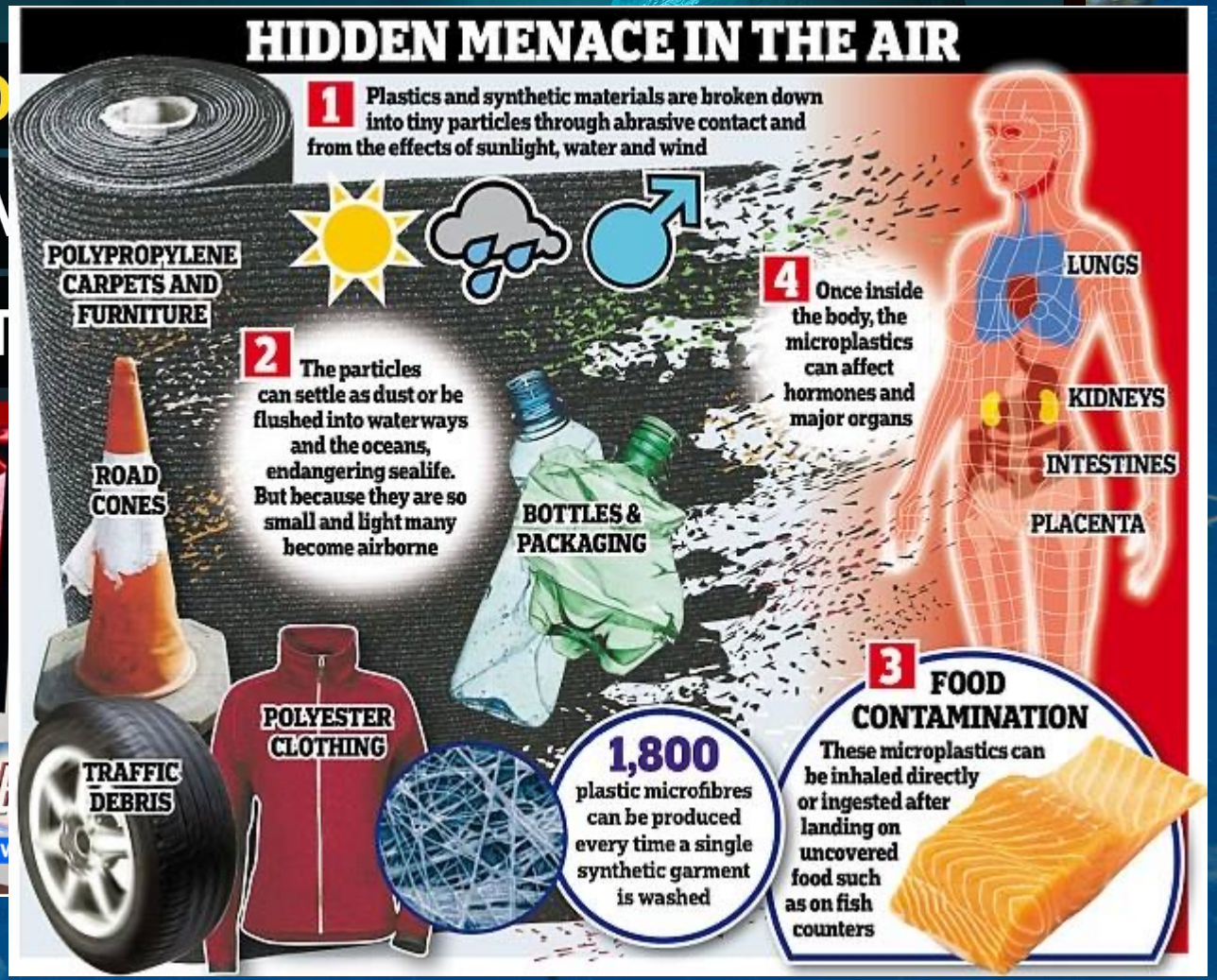
Microplastics detected in meat, milk and blood of farm animals

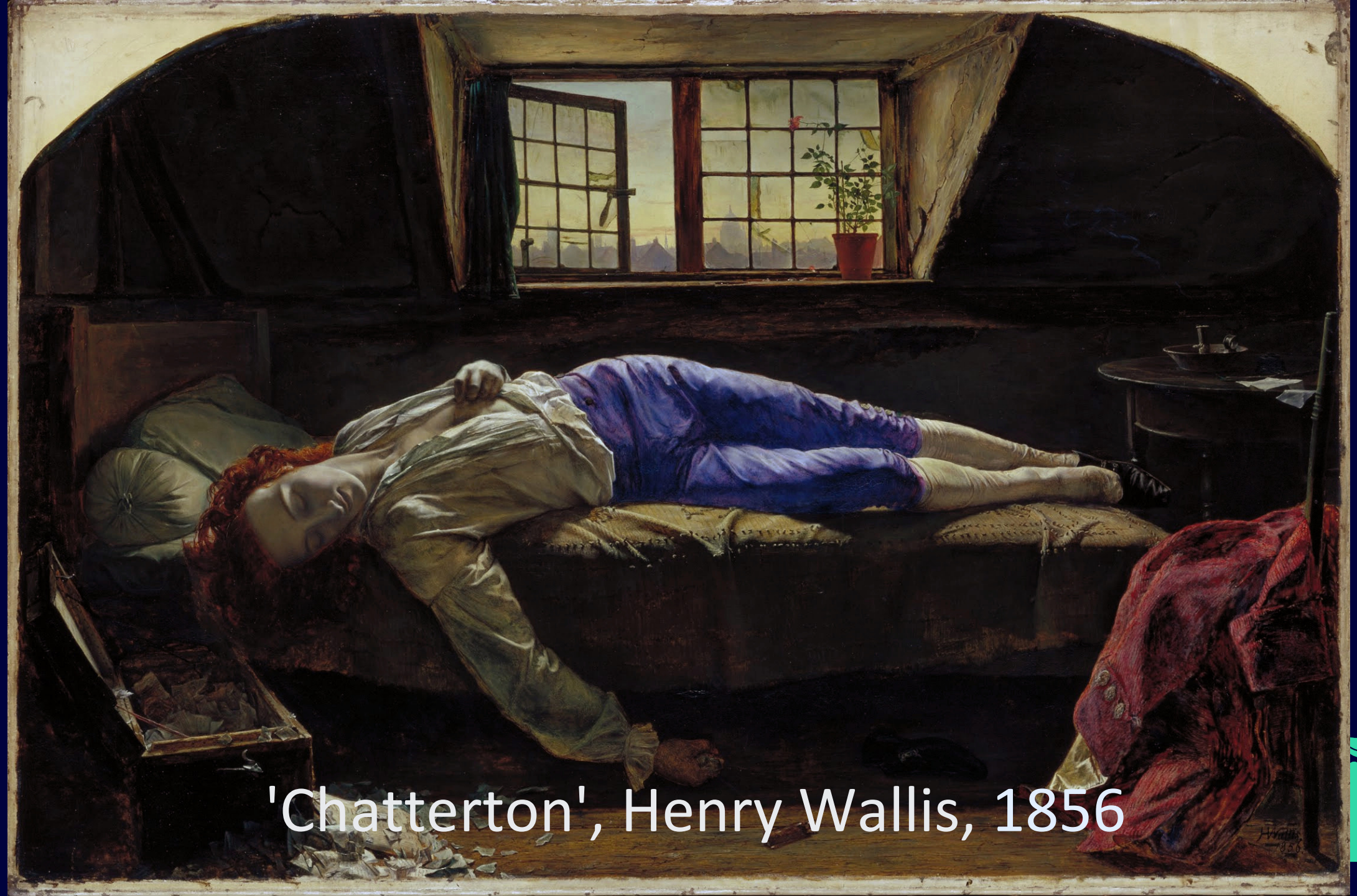
HEALTH

Do you have plastic in your b… people do, study shows



STUD…
YOU N…
WORT…





'Chatterton', Henry Wallis, 1856


44

Parkesine (1856)

Parkes, Alexander
1813 - 1890

Xylonite (1867)

Daniel Spill
1832-1887

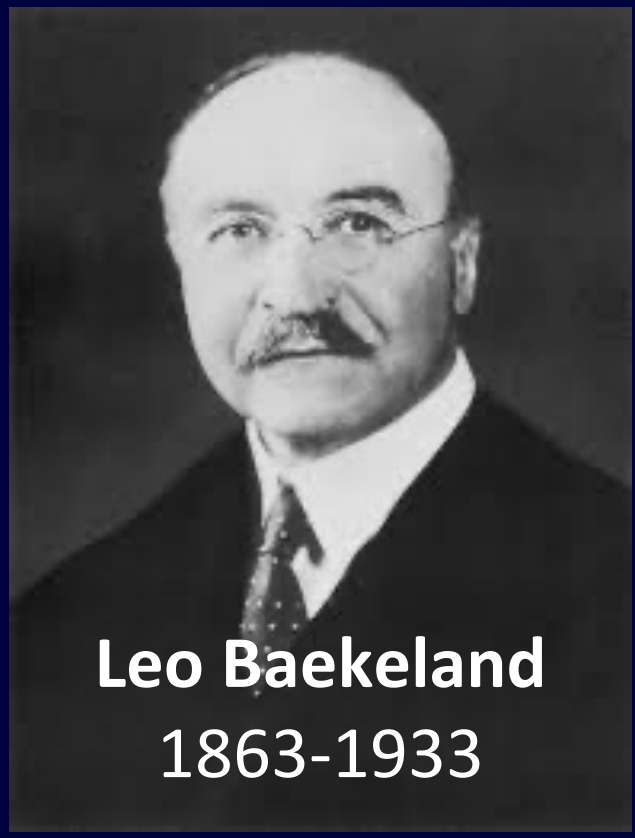
Celluloid (1870-73)

John Wesley Hyatt
1837-1929

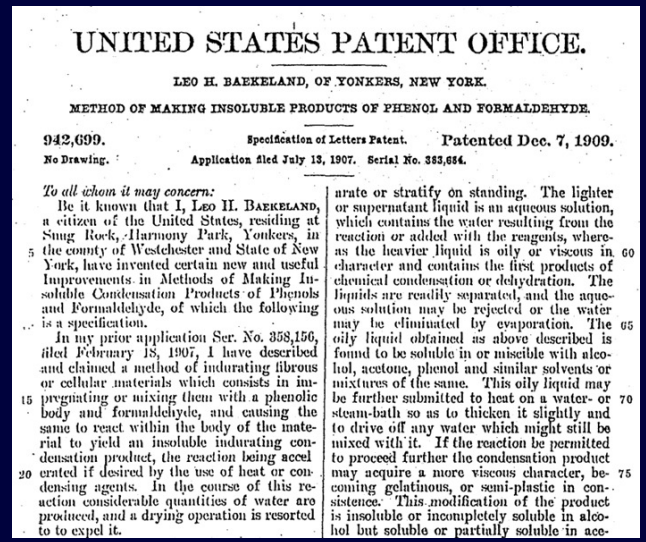
Bakelite®

Polyoxybenzylmethylenglycolanhydride (1909)

'The material of 1000 uses'



Leo Baekeland
1863-1933



UNITED STATES PATENT OFFICE.

LEO H. BAEKELAND, OF YONKERS, NEW YORK.

METHOD OF MAKING INSOLUBLE PRODUCTS OF PHENOL AND FORMALDEHYDE.

942,699. Specification of Letters Patent. Patented Dec. 7, 1909.

No Drawing. Application filed July 13, 1907. Serial No. 383,654.

To all whom it may concern:

Be it known that I, LEO H. BAEKELAND, a citizen of the United States, residing at Snug Rock, Harmony Park, Yonkers, in the county of Westchester and State of New York, have invented certain new and useful Improvements in Methods of Making Insoluble Condensation Products of Phenols and Formaldehyde, of which the following is a specification.

In my prior application Ser. No. 358,156, filed February 18, 1907, I have described and claimed a method of indurating fibrous or cellular materials which consists in impregnating or mixing them with a phenolic body and formaldehyde, and causing the same to react within the body of the material to yield an insoluble indurating condensation product, the reaction being accelerated if desired by the use of heat or condensing agents. In the course of this reaction considerable quantities of water are produced, and a drying operation is resorted to to expel it.

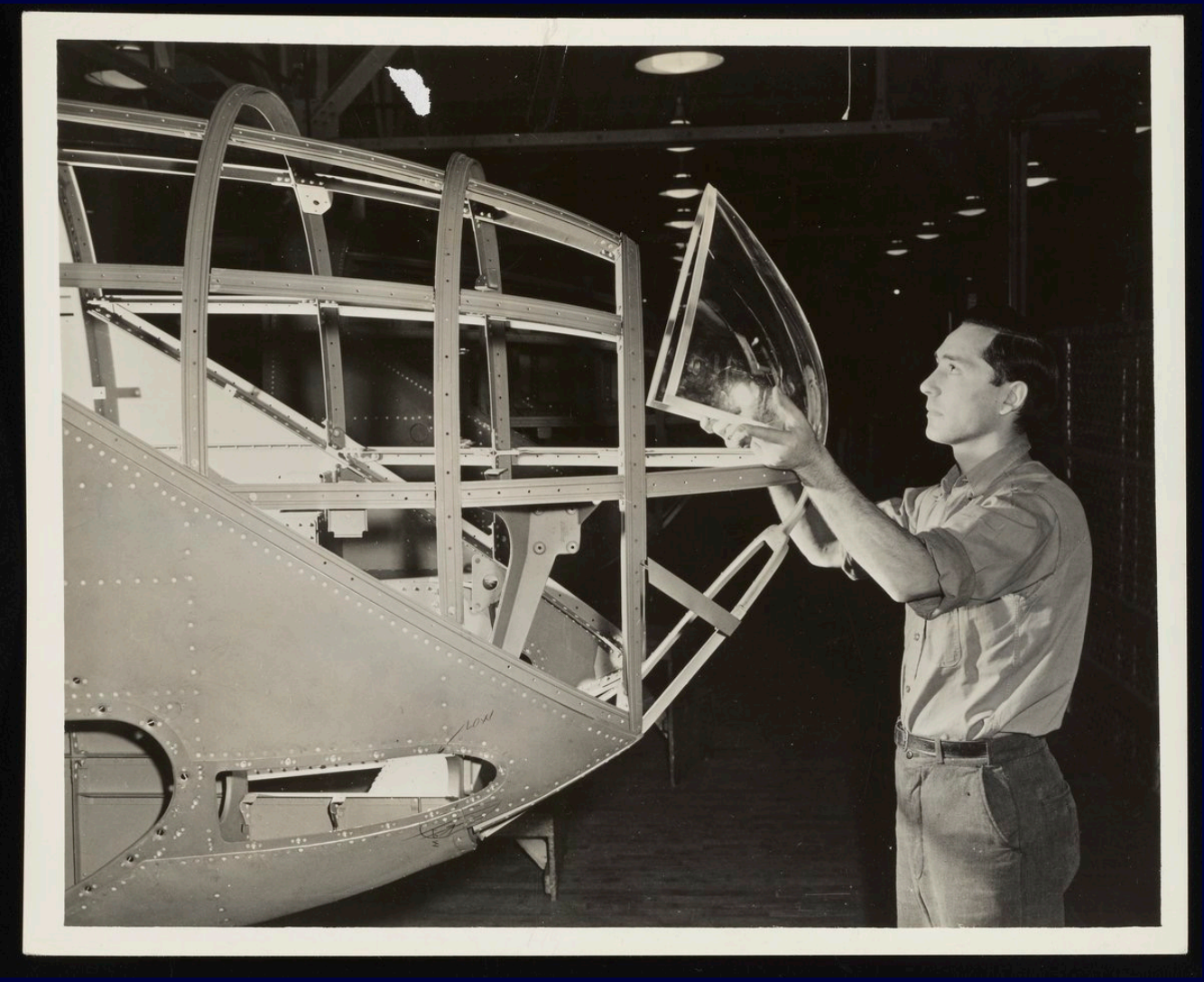
arate or stratify on standing. The lighter or supernatant liquid is an aqueous solution, which contains the water resulting from the reaction or added with the reagents, whereas the heavier liquid is oily or viscous in character and contains the first products of chemical condensation or dehydration. The liquids are readily separated, and the aqueous solution may be rejected or the water may be eliminated by evaporation. The oily liquid obtained as above described is found to be soluble in or miscible with alcohol, acetone, phenol and similar solvents or mixtures of the same. This oily liquid may be further submitted to heat on a water- or steam-bath so as to thicken it slightly and to drive off any water which might still be mixed with it. If the reaction be permitted to proceed further the condensation product may acquire a more viscous character, becoming gelatinous, or semi-plastic in consistence. This modification of the product is insoluble or incompletely soluble in alcohol but soluble or partially soluble in ace-

Neoprene (1931)
Nylon (1935)
Polytetrafluoroethylene – Teflon (1938)
Polyester (1950)
Kevlar (1965)

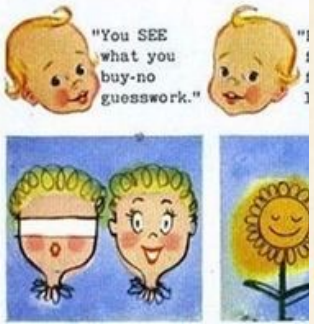
Perspex (1932)
Polyethylene (1933)

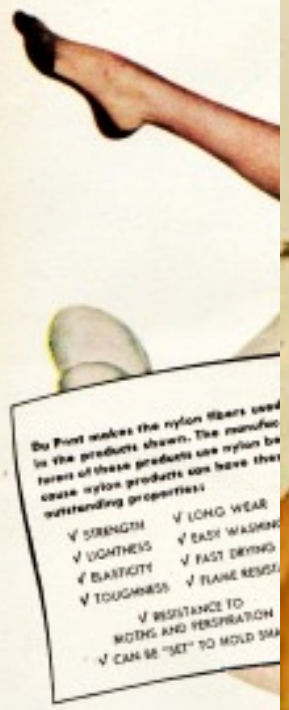
Polystyrene (1954)

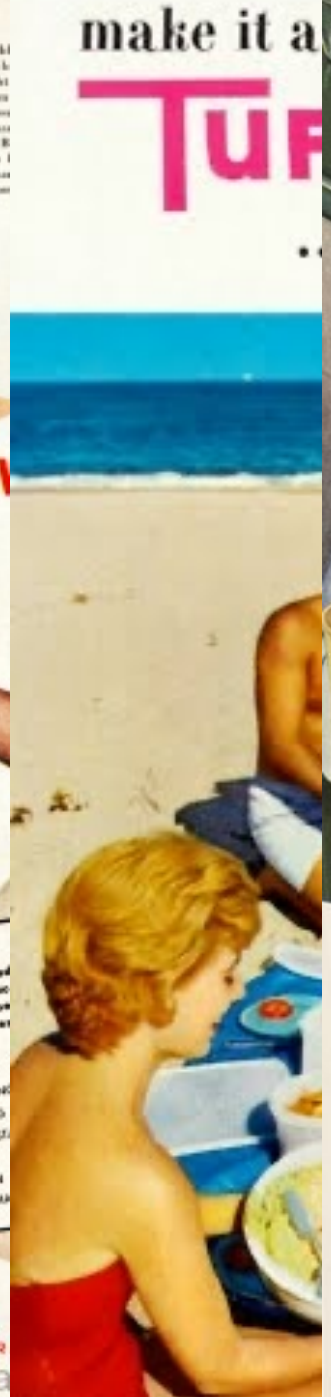
World War II

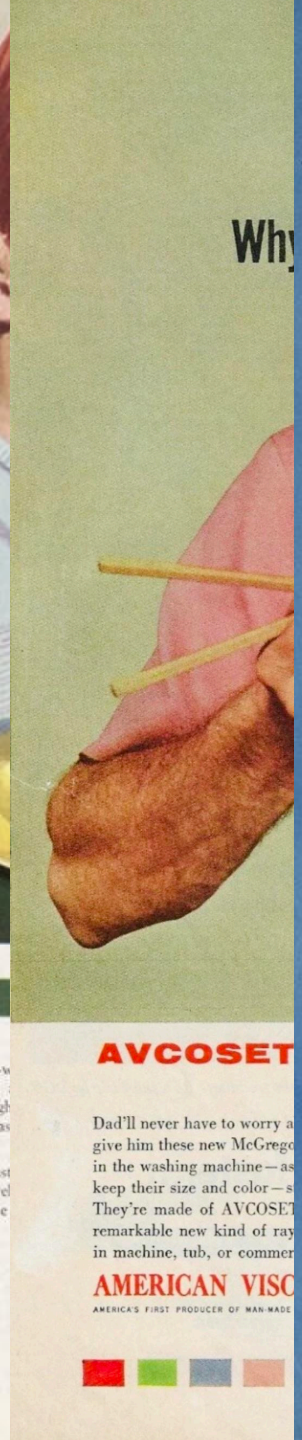


In the United States, plastic production increased by 300% during World War II.









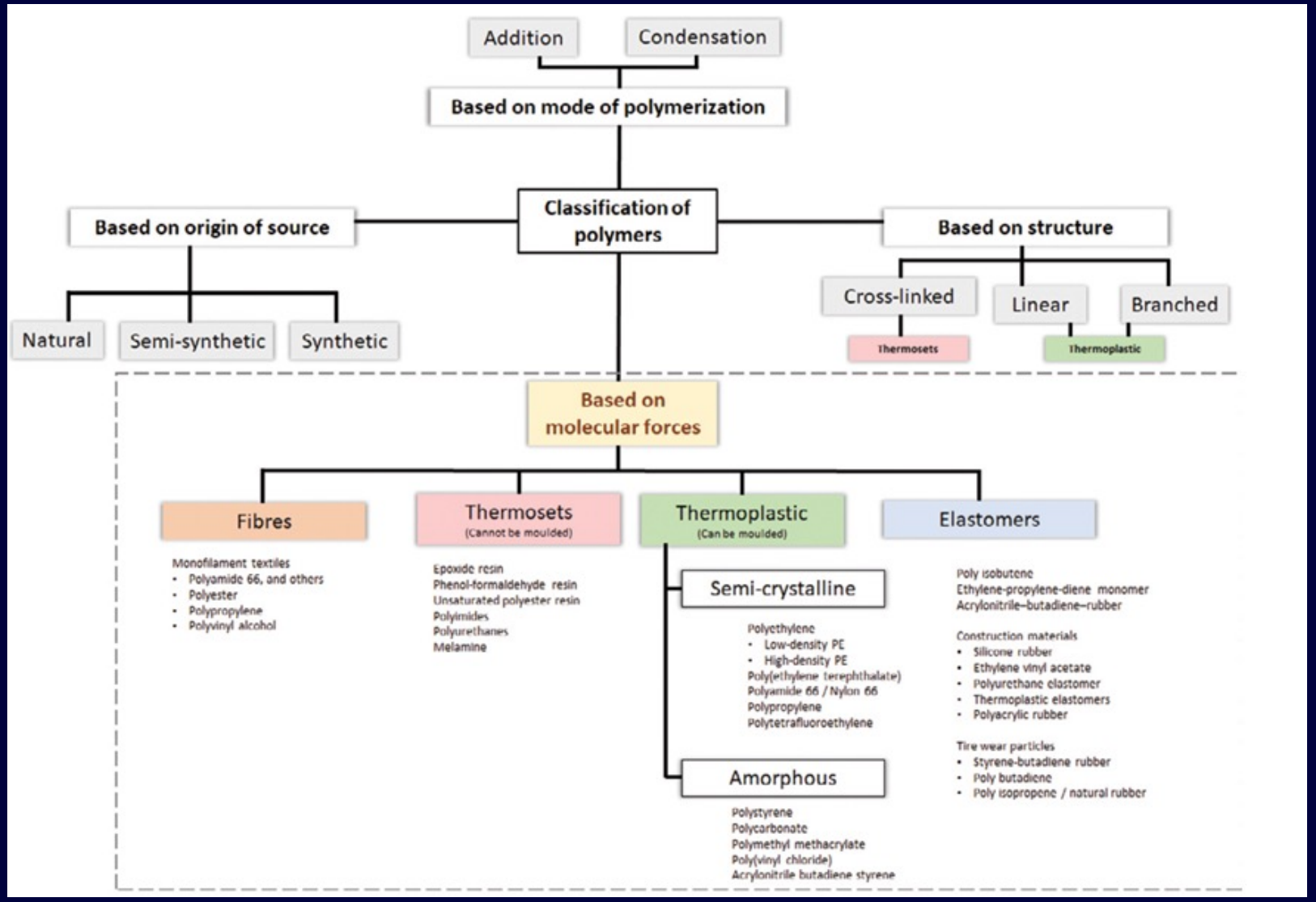
STILL STURDY AFTER 500 HOURS OF RUNNING WATER!

New Scott Plastic Cups

No cardboard taste...can't get soggy!
This plastic cup at "toss-away" prices
makes paper cups strictly old-fashioned!

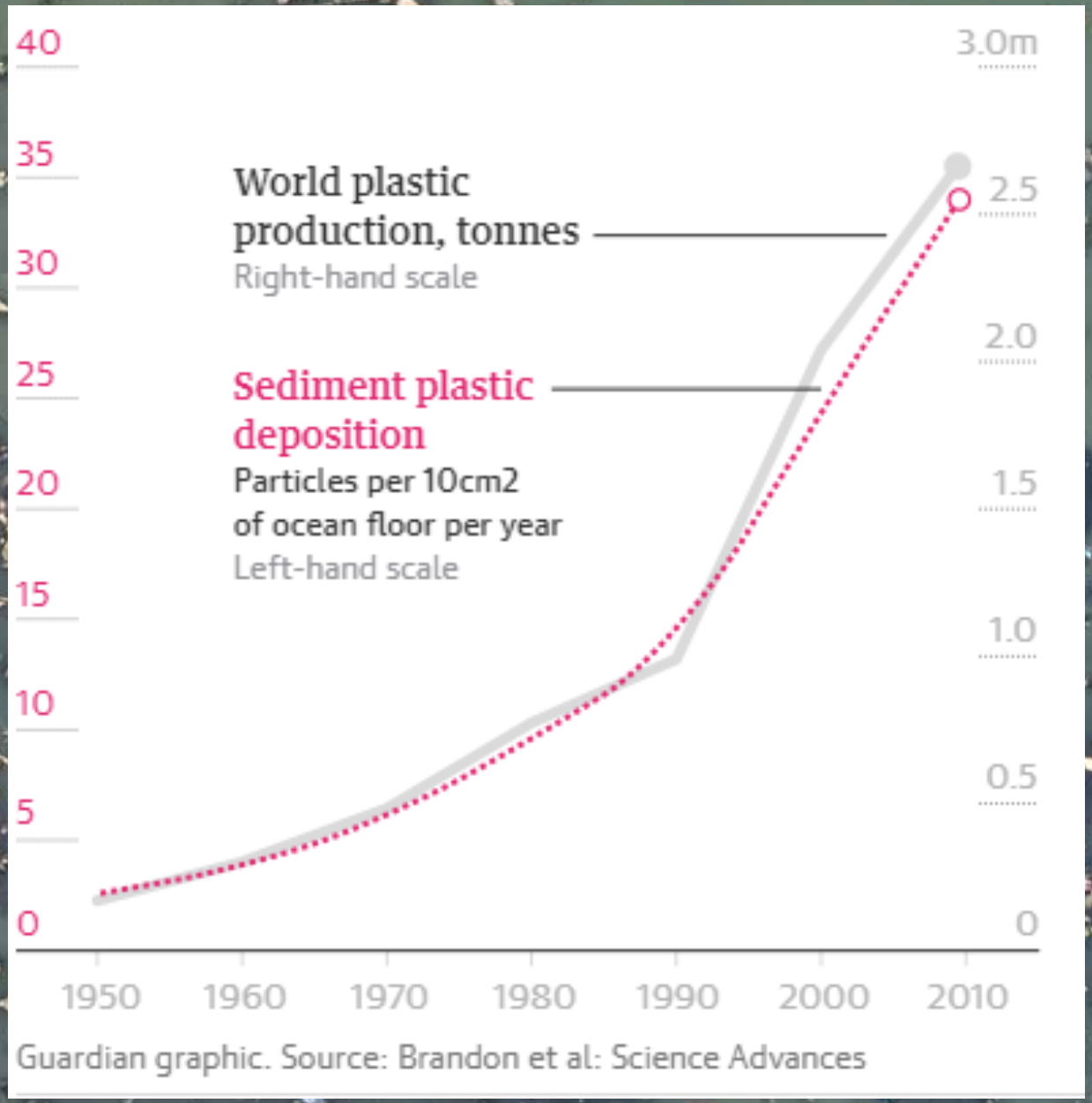
SCOTT MAKES IT BETTER FO

Classifications of manufactured and commonly encountered plastic materials

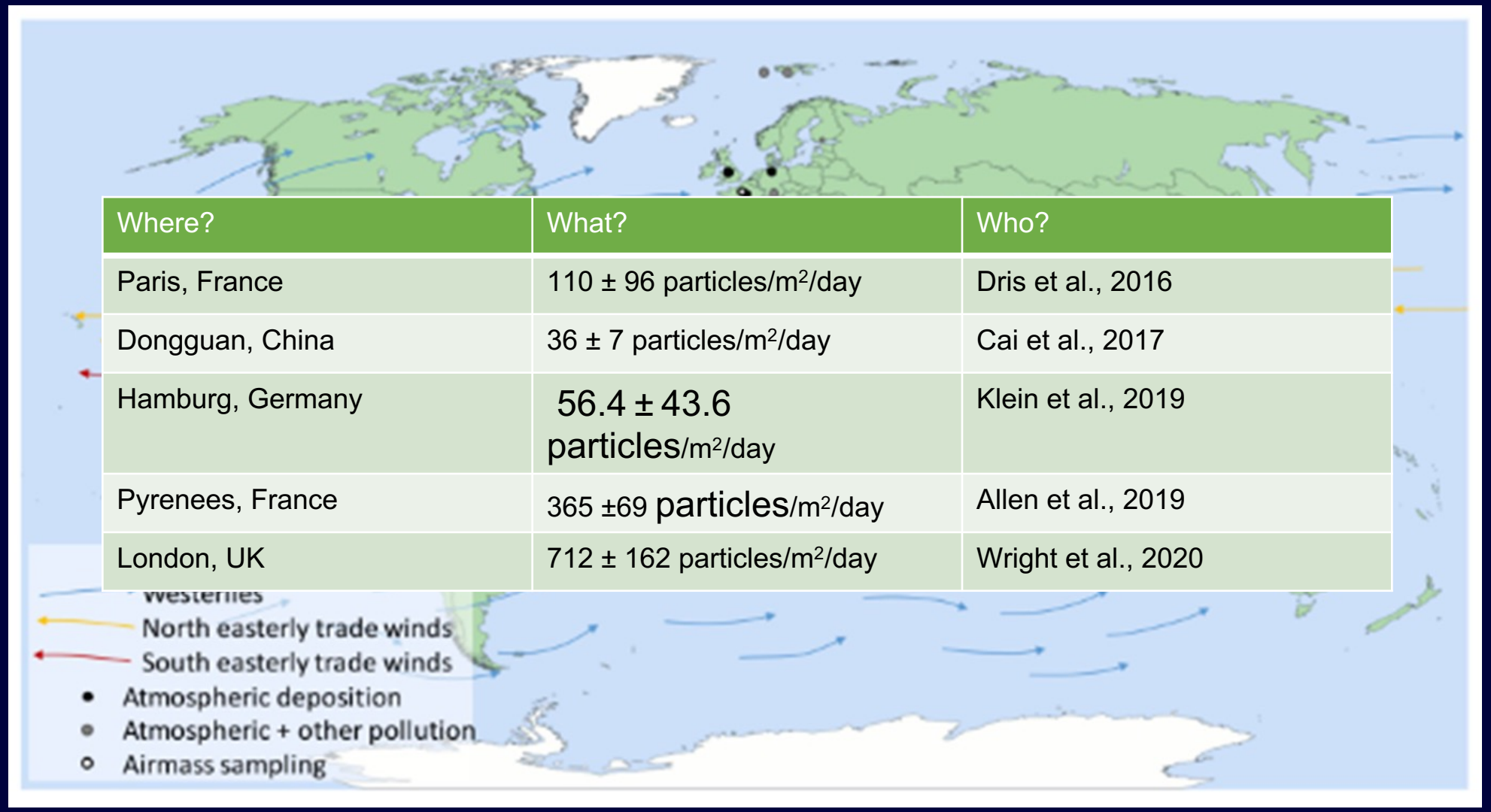


Plastic pollution in ocean sediments

Plasticene



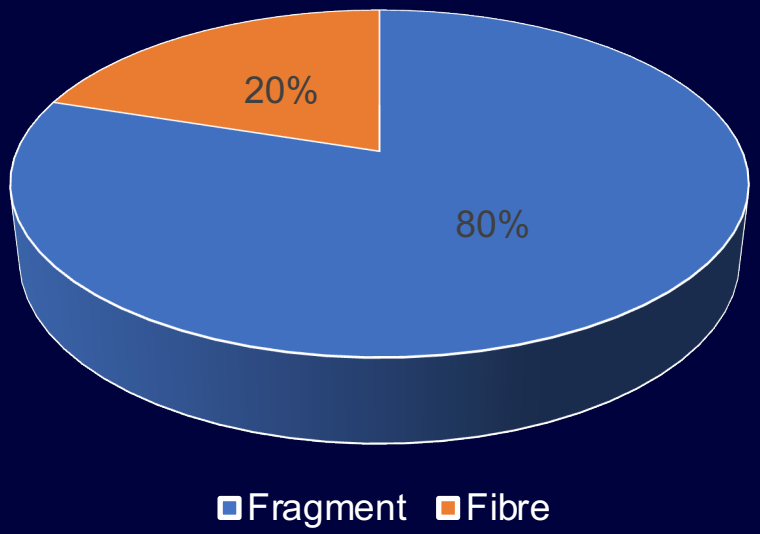
Atmospheric microplastic

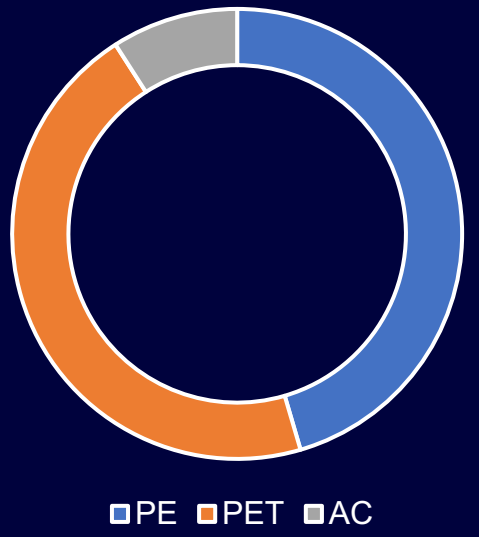


Where?	What?	Who?
Paris, France	110 ± 96 particles/m^2/day	Dris et al., 2016
Dongguan, China	36 ± 7 particles/m^2/day	Cai et al., 2017
Hamburg, Germany	56.4 ± 43.6 particles/m^2/day	Klein et al., 2019
Pyrenees, France	365 ±69 particles/m^2/day	Allen et al., 2019
London, UK	712 ± 162 particles/m^2/day	Wright et al., 2020

Zhang et al. 2020.

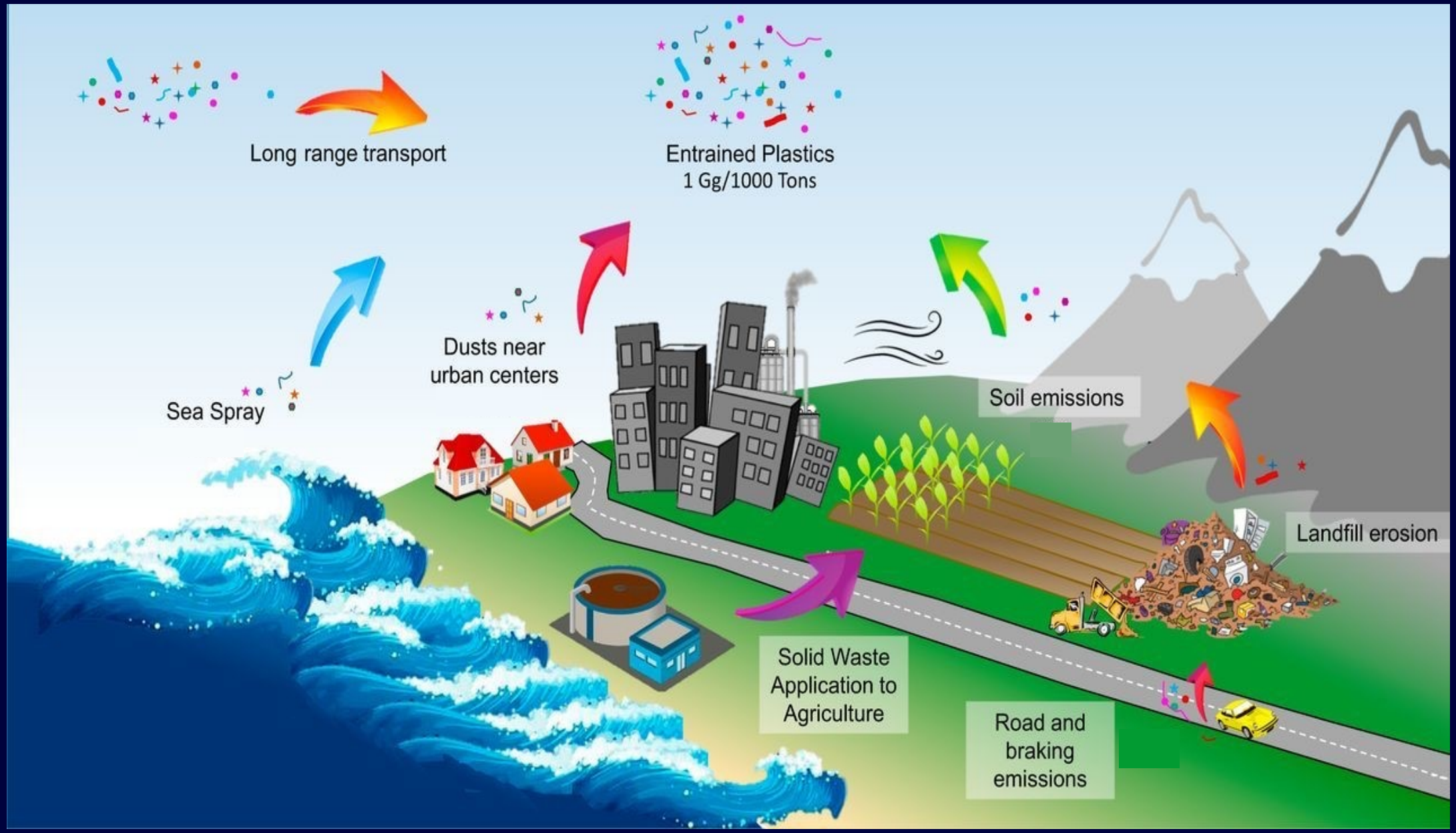
Microplastic$_{>10}$ characteristics





Search term ‘microplastic AND air’, up to Jan 2022. Inclusion criteria: primary research, quantifying microplastic in a volume of air, urban or indoor environment, uses an analytical technique which can discriminate between plastic types and uses this data to estimate concentration.

Wright and Borm, 2022



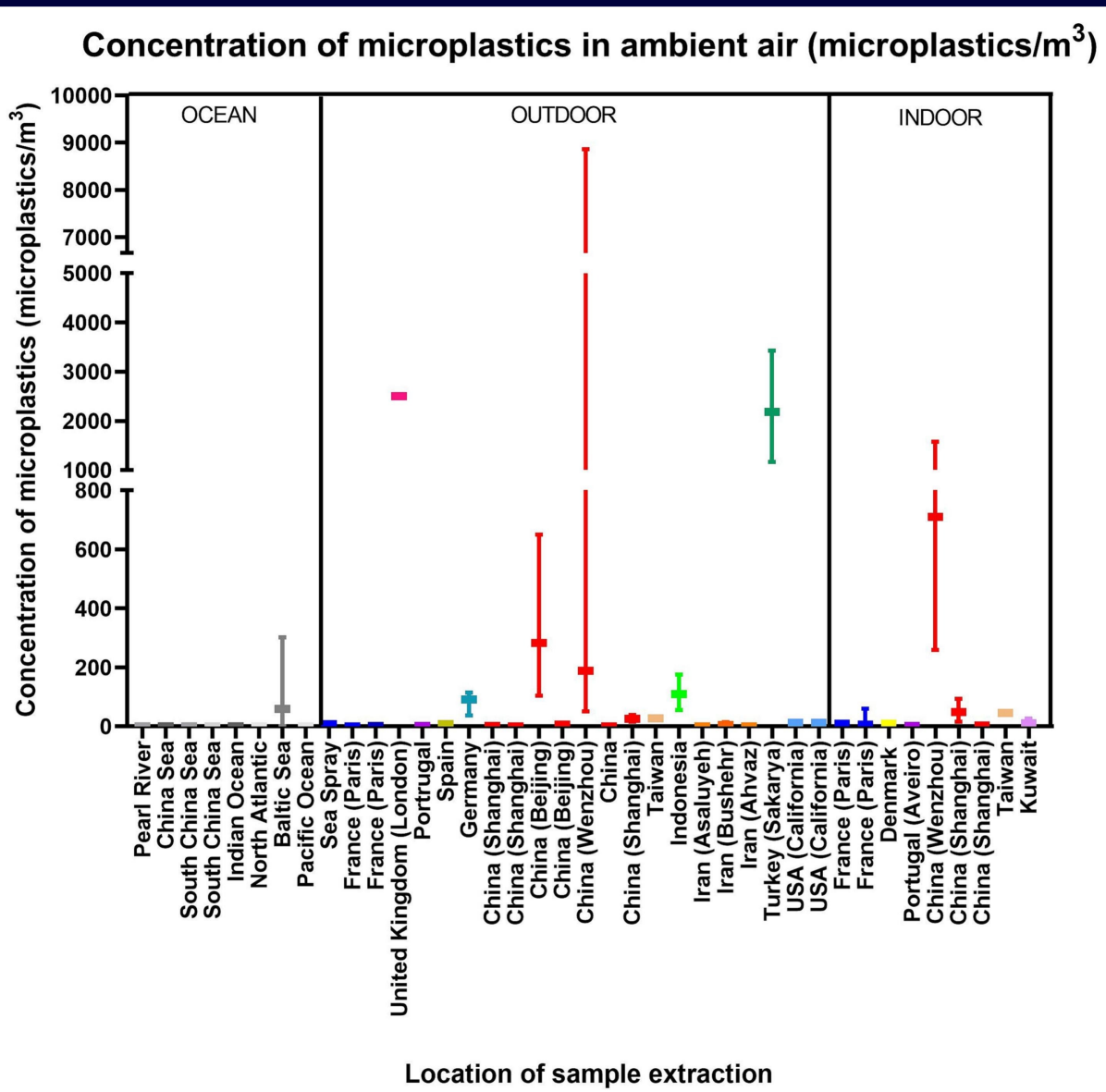
Adapted from Brahney et al., 2021

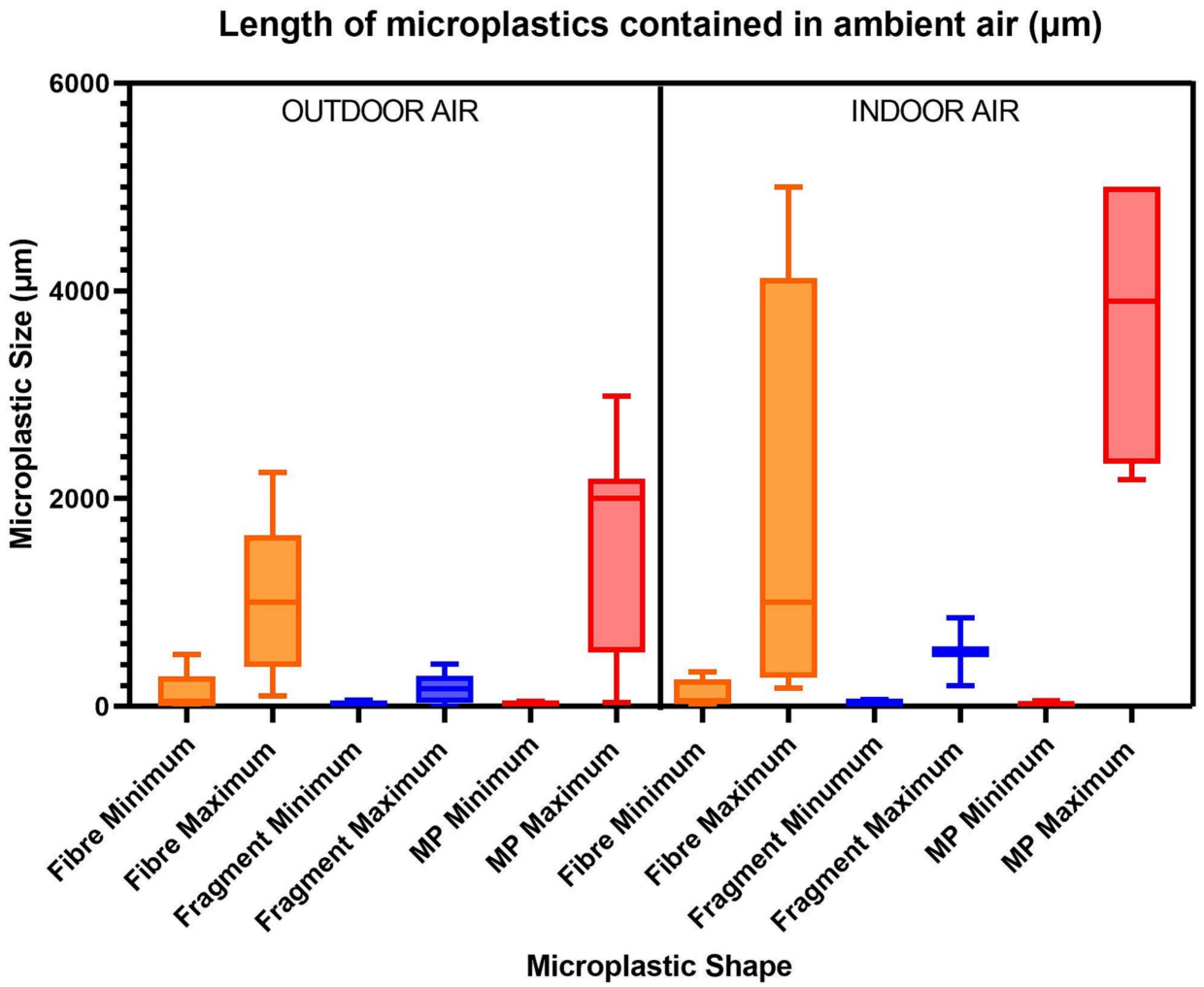
Source	Max	Reference
Bottled water		Ossman et al., 2018
Shellfish	1(	Leslie et al., 2017
Salt	19	Reni and Blaskovic, 2018
Air		Vianello et al., 2019
Deposition		Catarino et al., 2018
Total		

Source	Concentration (in numbers)	Size (in µm)	Estimated exposure (EE)
Seaweed (Baini et al., 2017)	22.57/sample	<500–5000	113/Nori wrap
	1.6 µg/g PAE	30% 1000–2500	1.9/OA pill
			0.4 PAE mg/Nori wrap
			0.007 mg PAE/OA pill
Salt (Yang et al., 2015)	**7–681/kg**	**55% <200**	**4/day**
		50–4300	
Salt (Iñiguez et al., 2017)	**128/kg**	**30–350**	**1/day**
Salt (Kosuth et al., 2018)	**212/kg**	**10–5000**	**2/day**
Sugar (G. Liebezeit & Liebezeit, 2013)	**249/kg**		**23/22 tsp**
Honey (G. Liebezeit & Liebezeit, 2013; G. L. Liebezeit, E, 2015)	**175/kg**	**10–3100**	**3.7/tbsp.**
Indoor air (Dris et al., 2017)	**5.4/m^3**	**50–3250**	**81/day**
Indoor air (Gasperi et al., 2015)		**50–80% 100–500**	
Outdoor air (Dris et al., 2017)	**0.9/m^3**	**50–1650**	**14/day**
Tap water (Kosuth et al., 2018)	**9.24/L**	**960 average**	**28/day**
Bottled water (Kosuth et al., 2018)	**3.57/L**	**970 average**	**4/day**
Beer (Kosuth et al., 2018)	**4.05/L**	**990 average**	**2/day**
Tea (Hernandez et al., 2019)	**12 × 10^9/cup**	**8.6–29.3 average**	**11.6 × 10^9/day**
	3.5 × 10^9/cup	**(and 22–156 nm)**	**3.5 × 10^9/day**
Soil (with compost) (Blasing & Amelung, 2018)	2.38–180/kg	>1–5000	**<0.036/day**
	1200 mg/kg		**<0.24/day**
Total (fibers per day)		**Diet dependent**	**>50-to-billions**

*Bottled water intake (worst case) fo
**Shellfish and salt intake based on
***Inhalation intake based on an adu

Zarus et al., 2021

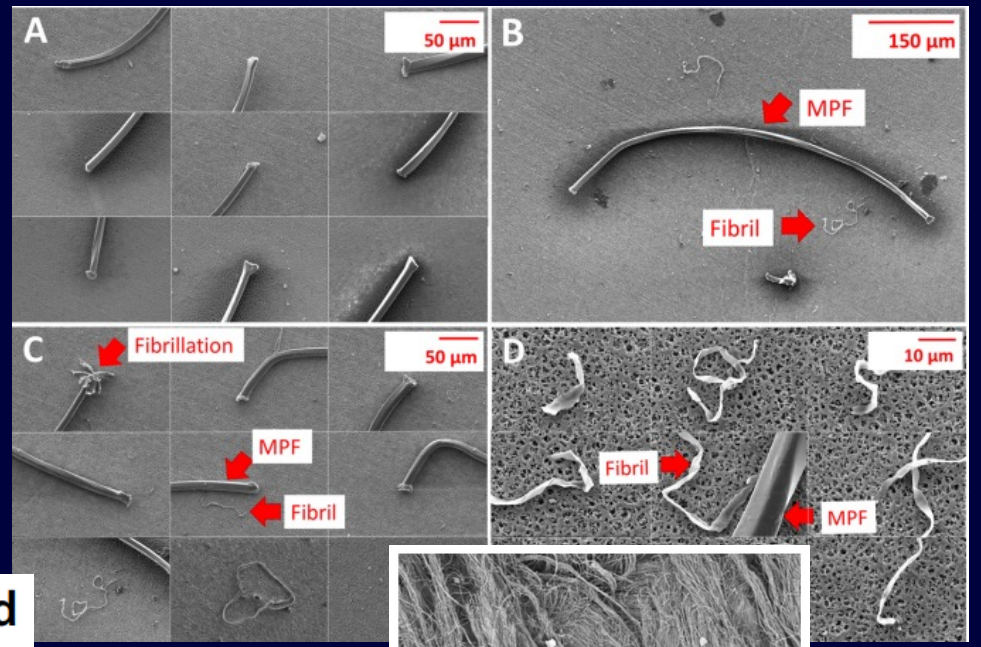




O' Brien et al., 2023.

Is there a plastic component in ultrafines?

Evidence for fibril, and nanoplastic emissions (2.1× 10^{11} per gram material)
Nanofibres (200 nm) are produced
10s of ng/mL PET, PVC in snow (<0.2 µm)
Oxidation -> surface ablation -> nanoplastic



Micro- and Nanoplastics in Alpine Snow: A New Method for Chemical Identification and (Semi)Quantification in the Nanogram Range

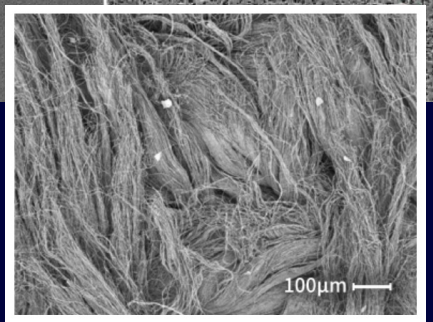
Dušan Materić*, Anne Kasper-Giebl, Daniela Kau, Marnick Anten, Marion Greilinger, Elke Ludewig, Erik van Sebille, Thomas Röckmann, ar

Characterization of Nanoplastics, Fibrils, and Microplastics Released during Washing and Abrasion of Polyester Textiles

Tong Yang, Jialuo Luo, and Bernd Nowack*

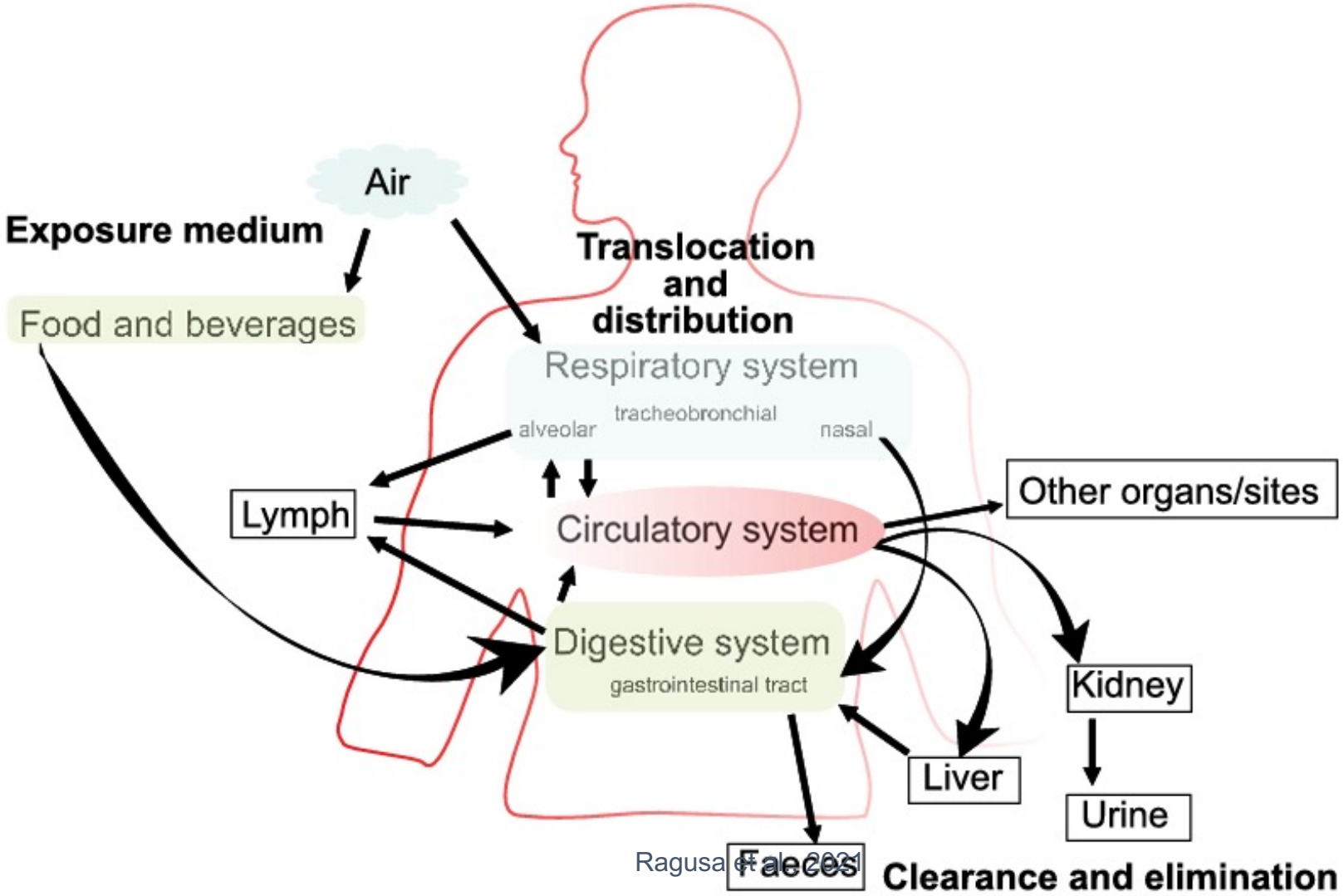
Formation of Fiber Fragments during Abrasion of Polyester Textiles

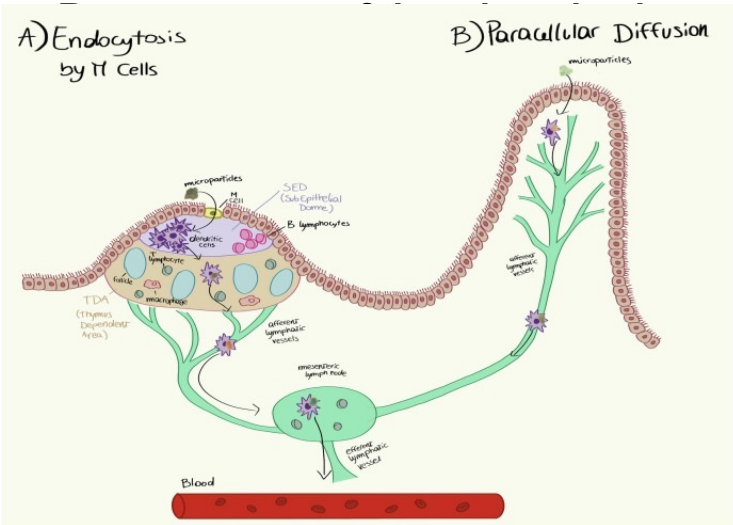
Yaping Cai, Denise M. Mitrano, Rudolf Hufenus, and Bernd Nowack*

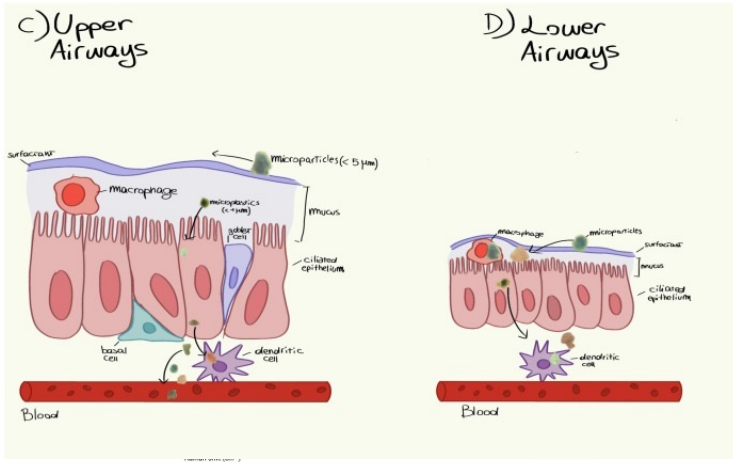


Surface of *NANOFRONT*® fabric

Toxicokinetic and microplastics







Ragusa et al., 2021

Micro (nano) plastic translocation

- Most ingested NP are detected in the mucus lining of the intestinal tract, and do not permeate the epithelium
- The small intestine provides an effective barrier against NP uptake
  - This may be compromised by pathophysiological condition, e.g. impairment of the mucus film layer
- Particles >1.5 µm are not expected to enter the capillaries of tissues and therefore are not expected to penetrate deeply into organs
- Uptake of particles >20 µm into normal cells/organs appears to be minimal, but information is lacking

A brief history of microplastics

Blood
Breast milk
Lung tissue
Placenta
…. etc

Where are the health effects?

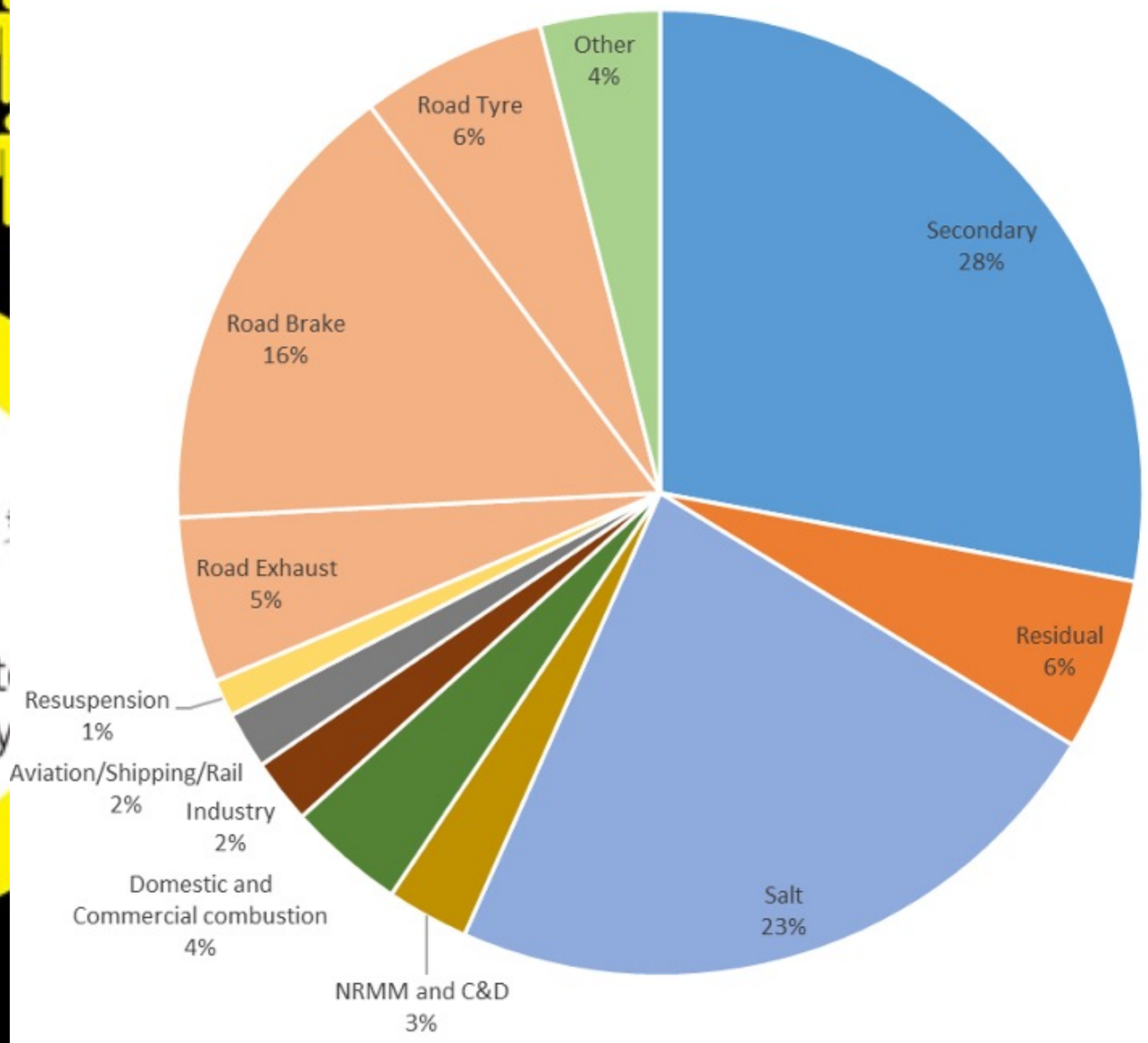
Myth or Menace?

Air pollution - th

9 in 10
people breathe polluted air worldwide

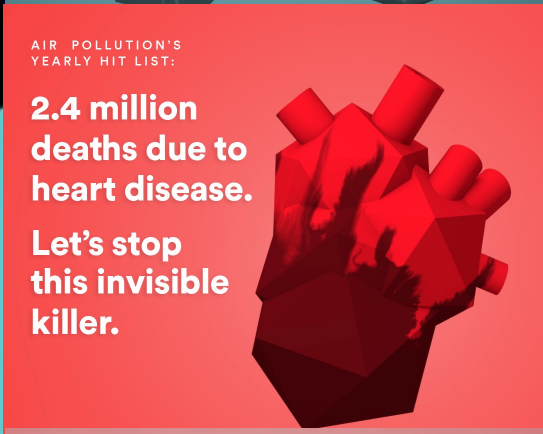
98%
of cities with more than 100,000 inhabitants fail t meet air quality guidelines

Source apportionment for the highest PM2.5 concentration locations in London in 2020



sed
old
n

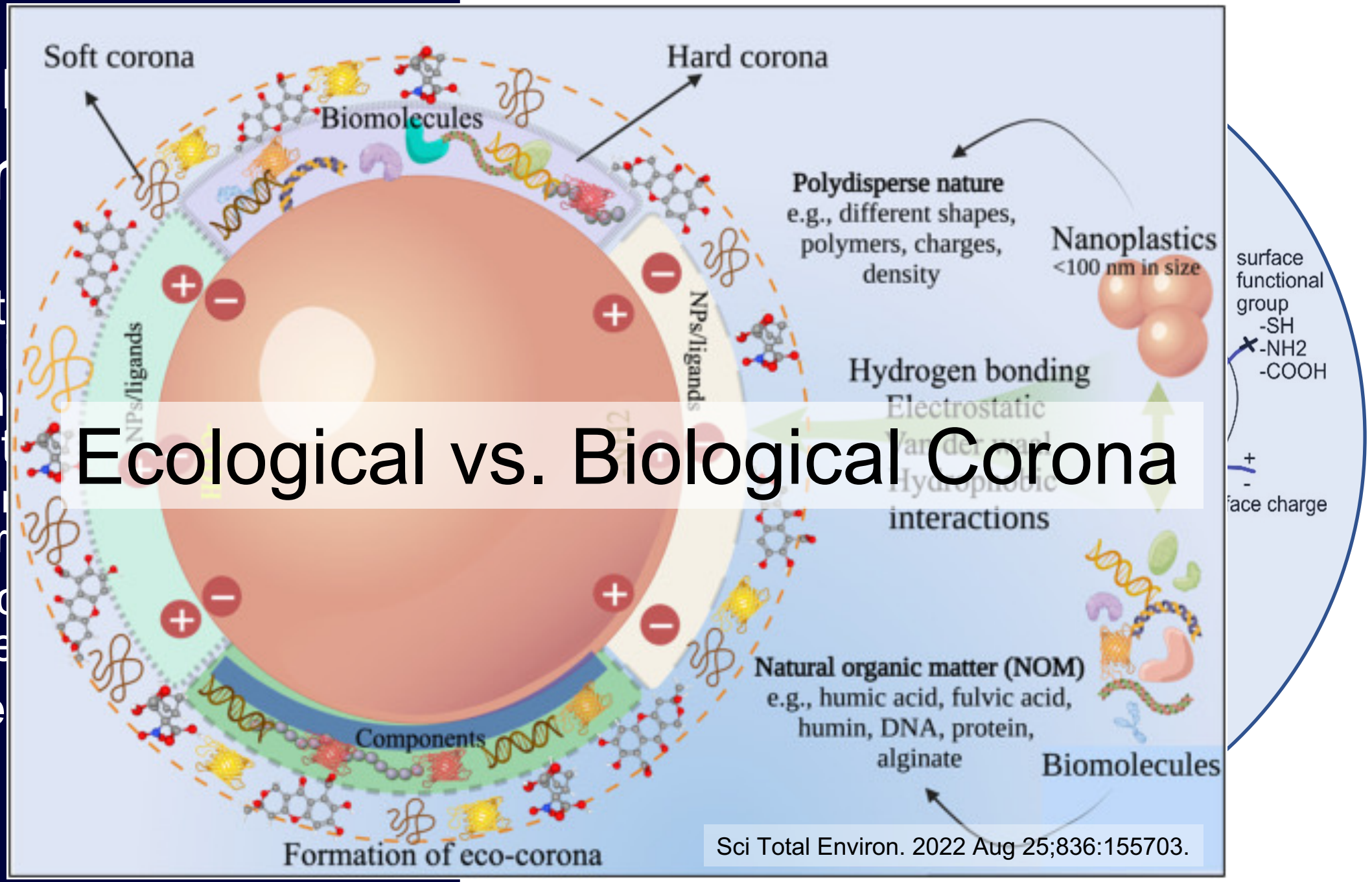
: UN/WHO



Risk = Hazard x Exposure

Mic
cor

- Occupat
(coal, sil
pollution
nanomat
  - relatio
prope
- Physicoc
propertie
- **Dose-re**



Sci Total Environ. 2022 Aug 25;836:155703.

Occupational Exposures: Flock worker's lung

a)

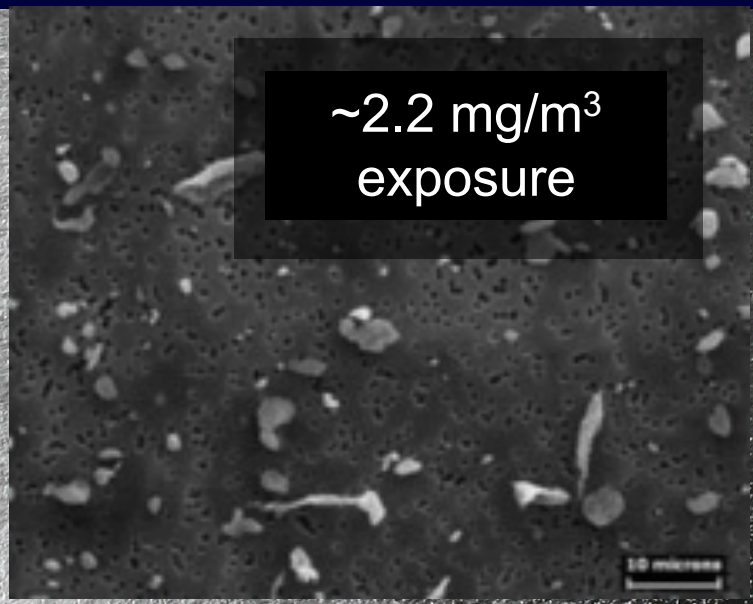
Interstitial lung disease

IR all interstitial lung disease = 48 (95% CI 23-88)

IR IPF = 258 (95% CI 104-530)

b)

PE flock worker in Spain, PP flock workers in Turkey, Rayon flock workers



~2.2 mg/m^3 exposure

- K 07;
  Burkhart et al., 1999.

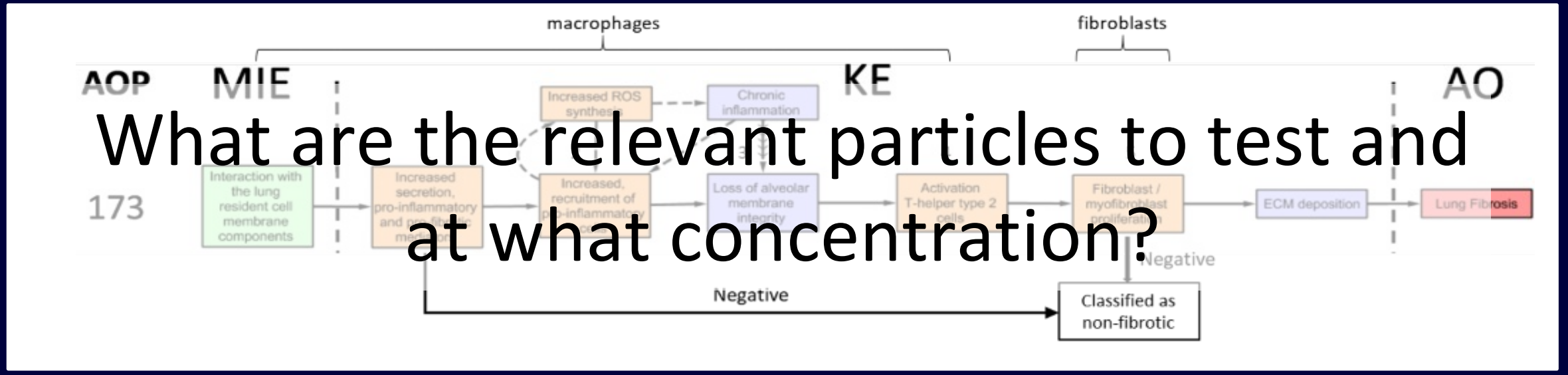
Inflammation | Granulomas | Fibrosis

Lessons from particle/fibre toxicology toxicology

Particles, properties, characteristics	Environmental microplastics
High aspect ratio fibres	>5 µm diameter Thin fibrils under mechanical stress (~1-2 µm)
Transition metals	Beached plastic pellets: **Hg**, **Cr** [~10 µg g^{-1}], **V** [~5 µg g^{-1}], **Pb** [~44 µg g^{-1}];[1] **Fe** [~228 µg g^{-1}];[2] River sediment: **Cd** [~17.6 µg g^{-1}], **Ni** [~2.4 µg g^{-1}], **Pb** [93.2 µg g^{-1}], **Cu** [500.6 µg g^{-1}][3]
Hydrophobicity	UV oxidation - ↓ hydrophobic surface groups[4]
Surface charge (e.g., positive) and reactivity (e.g., silanols)	↑ Negative charges; ↑ Oxygen-containing functional groups[4]
Crystallinity	↑ Crystallinity[4]
Biopersistence	Undetermined (*in vitro* – yes;[5] *in vivo* – no[6])
Soluble toxicants	Additives, metals

1. Coley et al., 2019; 2. Vendolin et al., 2018; 3. Wang et al., 2017; 4. Liu et al., 2020; 5. Law et al., 1990; 6. Warheit et al., 2003.

Adverse Outcome Pathway for persistent particles



What are the relevant particles to test and at what concentration?

- *In vitro* inflammation, oxidative stress and cytotoxicity – upstream events to predict in vivo tissue-level damage.
- The uncontrolled resolution of that damage leads to scarring and loss of function

Halappanavar et al., 2019

ANATOMY OF PLASTICS

WHAT'S IN MY PLASTICS?

UN environment programme

1. **MONOMERS AND POLYMERS**
constitute main building blocks of plastic material

2. **ADDITIVES**
bring desired functionality to the plastic material

3. **OTHER INTENTIONALLY ADDED SUBSTANCES**
such as starting materials and catalysts

4. **NON-INTENTIONALLY ADDED SUBSTANCES**
such as solvents, cleaning agents, or impurities from manufacturing or recycling

BREAKDOWN
most widely produced plastic additives*

*Source: Geyer et al. 2017

Plasticizers
to make plastic softer and flexible
e.g. phthalates, chlorinated parafins

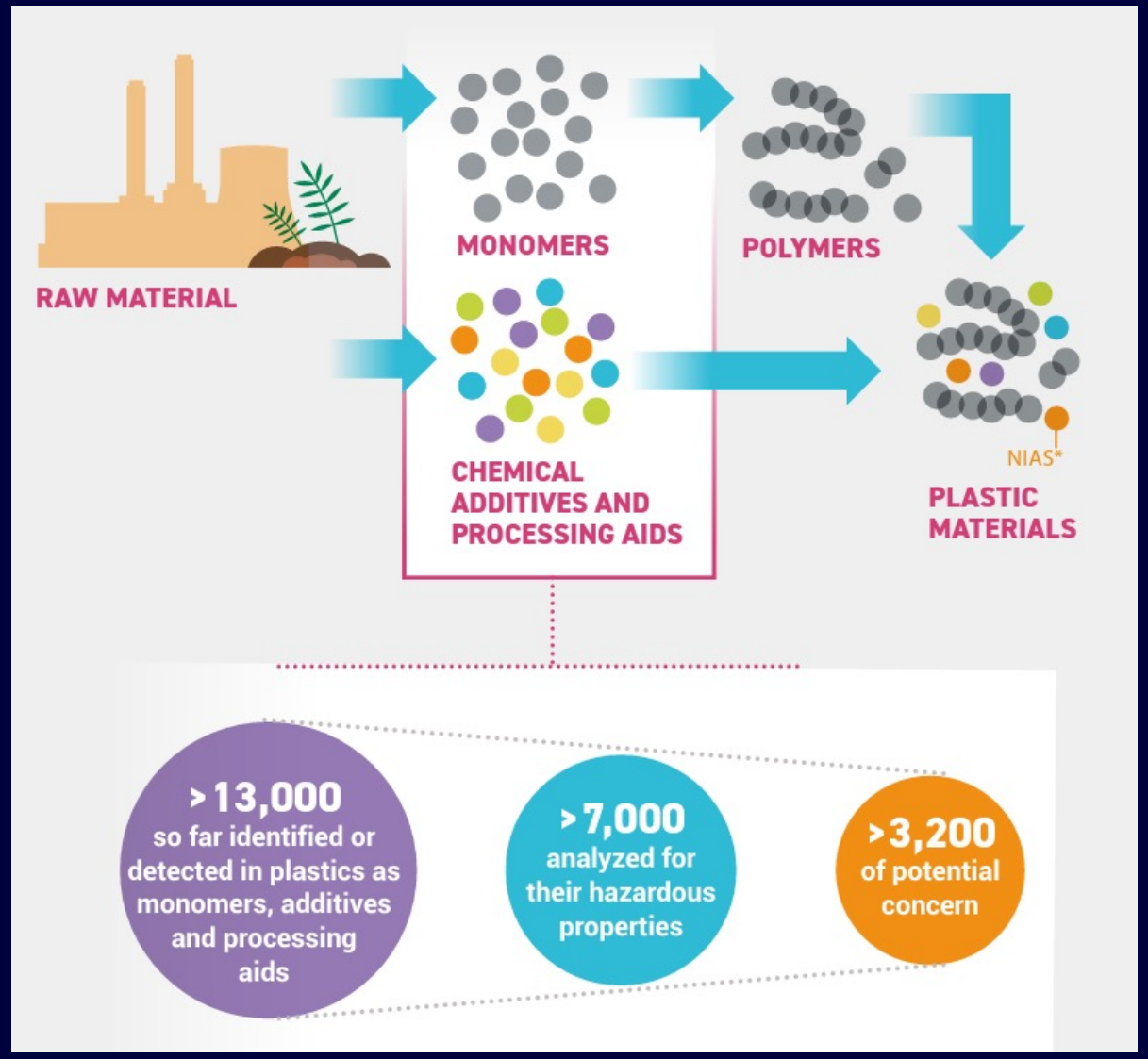
Fillers
that occupy space without changing functional properties
e.g. mica, talc or clay

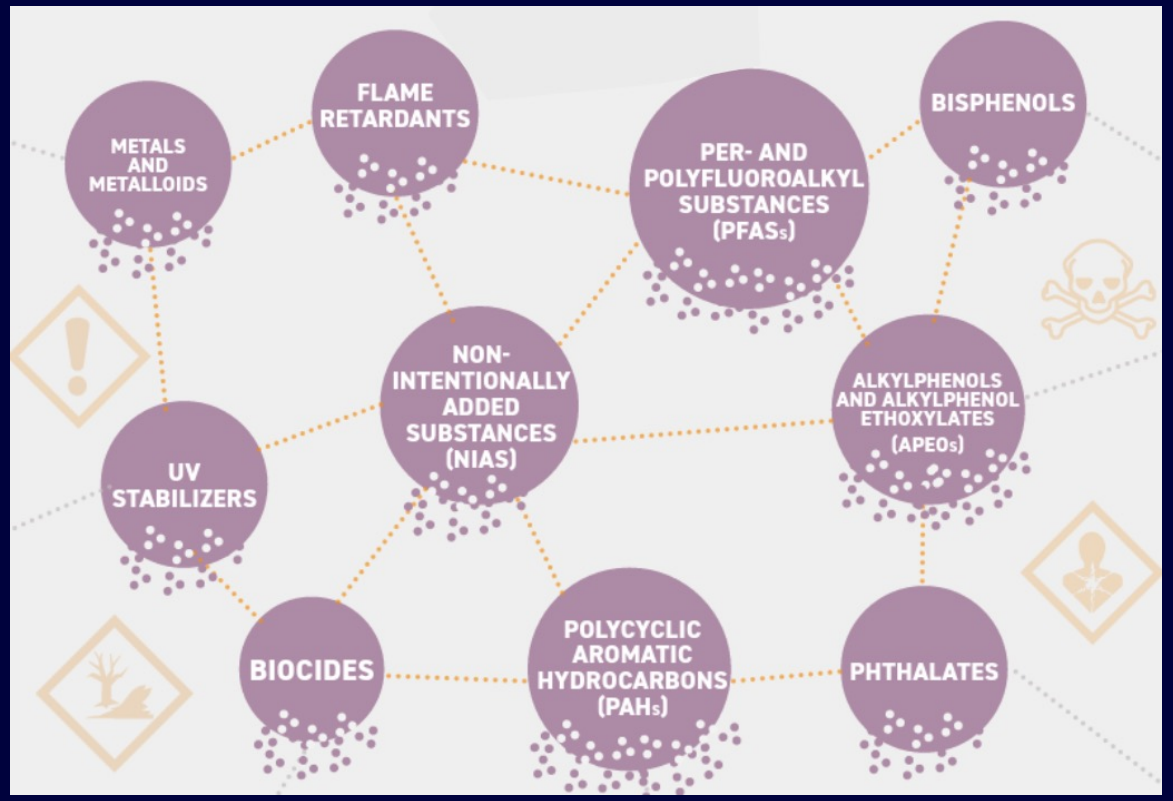
Flame retardants
to reduce flammability and prevent spread of fire - e.g. brominated and chlorinated flame retardants

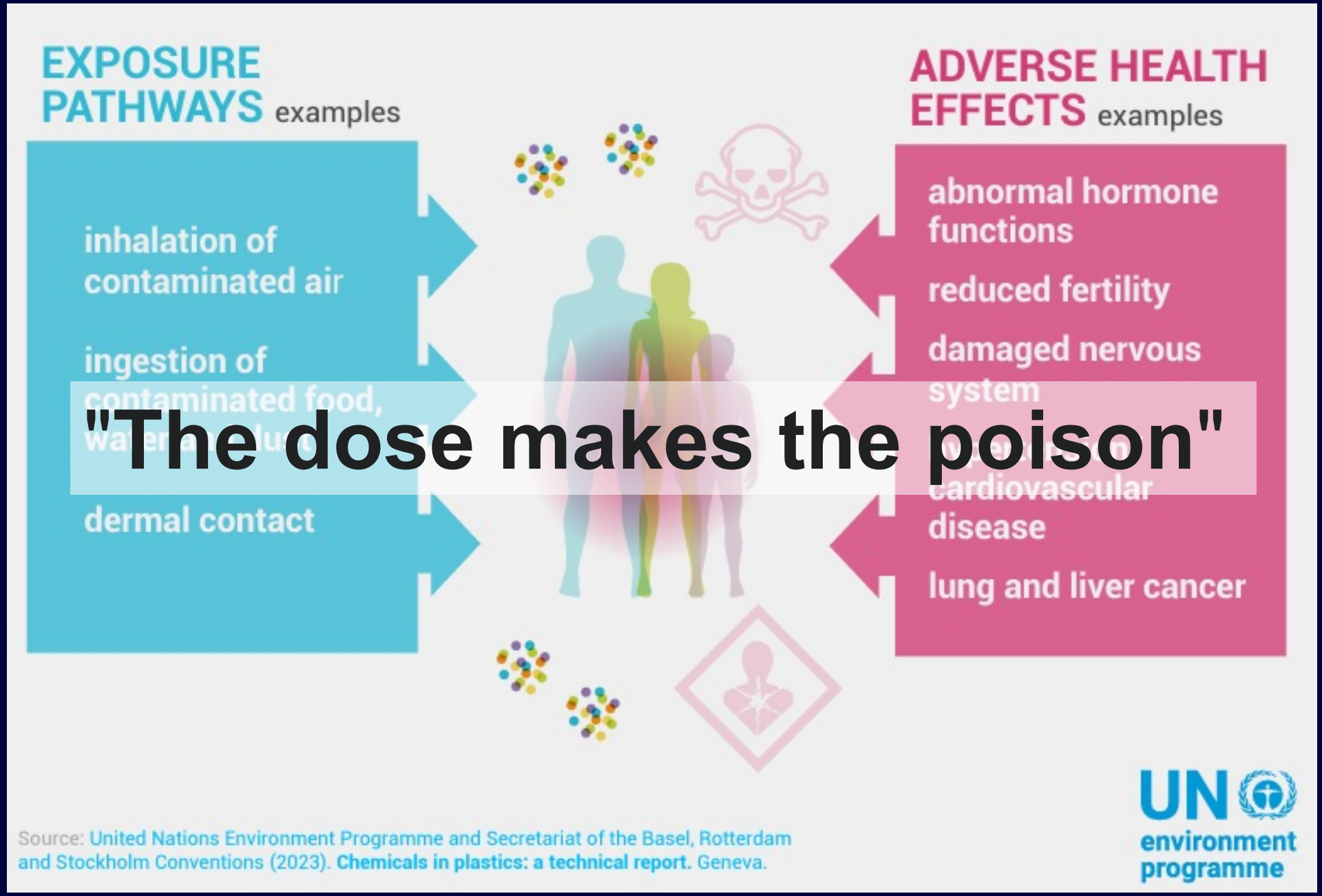
Other
including colorants, antioxidants, heat and light stabilizers, lubricants, biocides or antistatic agents

Source: United Nations Environment Programme and Secretariat of the Basel, Rotterdam and Stockholm Conventions (2023). **Chemicals in plastics: a technical report.** Geneva.

Additive Hazards



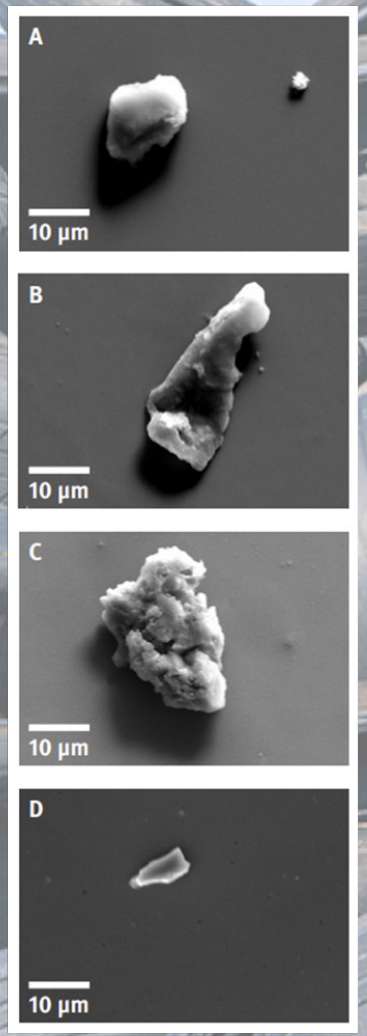


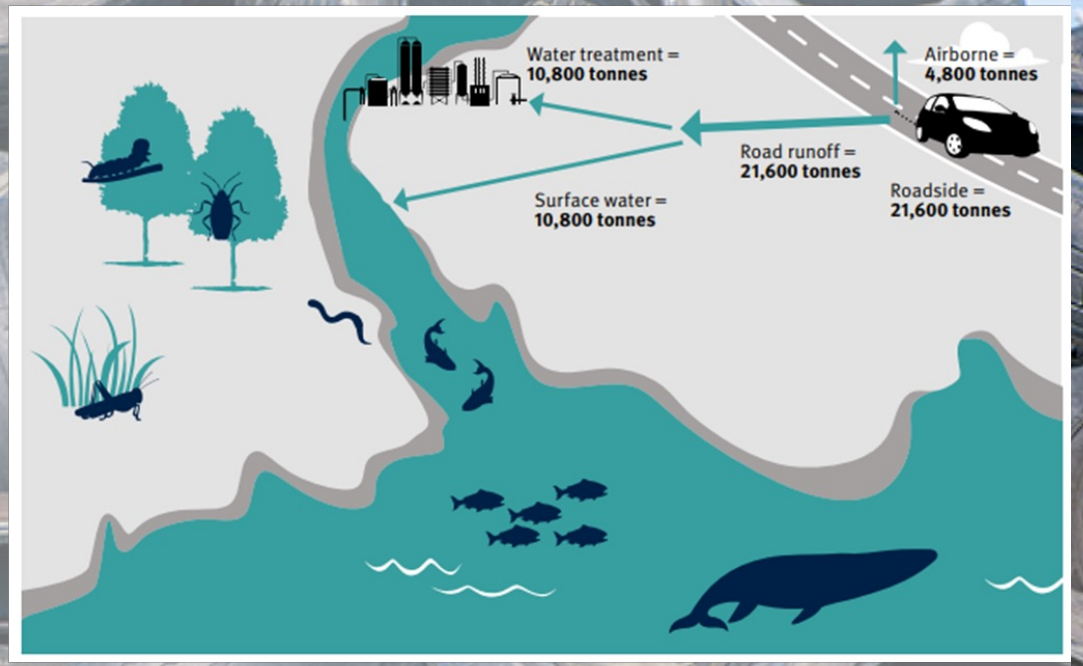

EXPOSURE PATHWAYS examples
inhalation of contaminated air
ingestion of contaminated food,
dermal contact
ADVERSE HEALTH EFFECTS examples
abnormal hormone functions
reduced fertility
damaged nervous system
cardiovascular disease
lung and liver cancer
"The dose makes the poison"
Source: United Nations Environment Programme and Secretariat of the Basel, Rotterdam and Stockholm Conventions (2023). Chemicals in plastics: a technical report. Geneva.
UN environment programme

Tyre wear

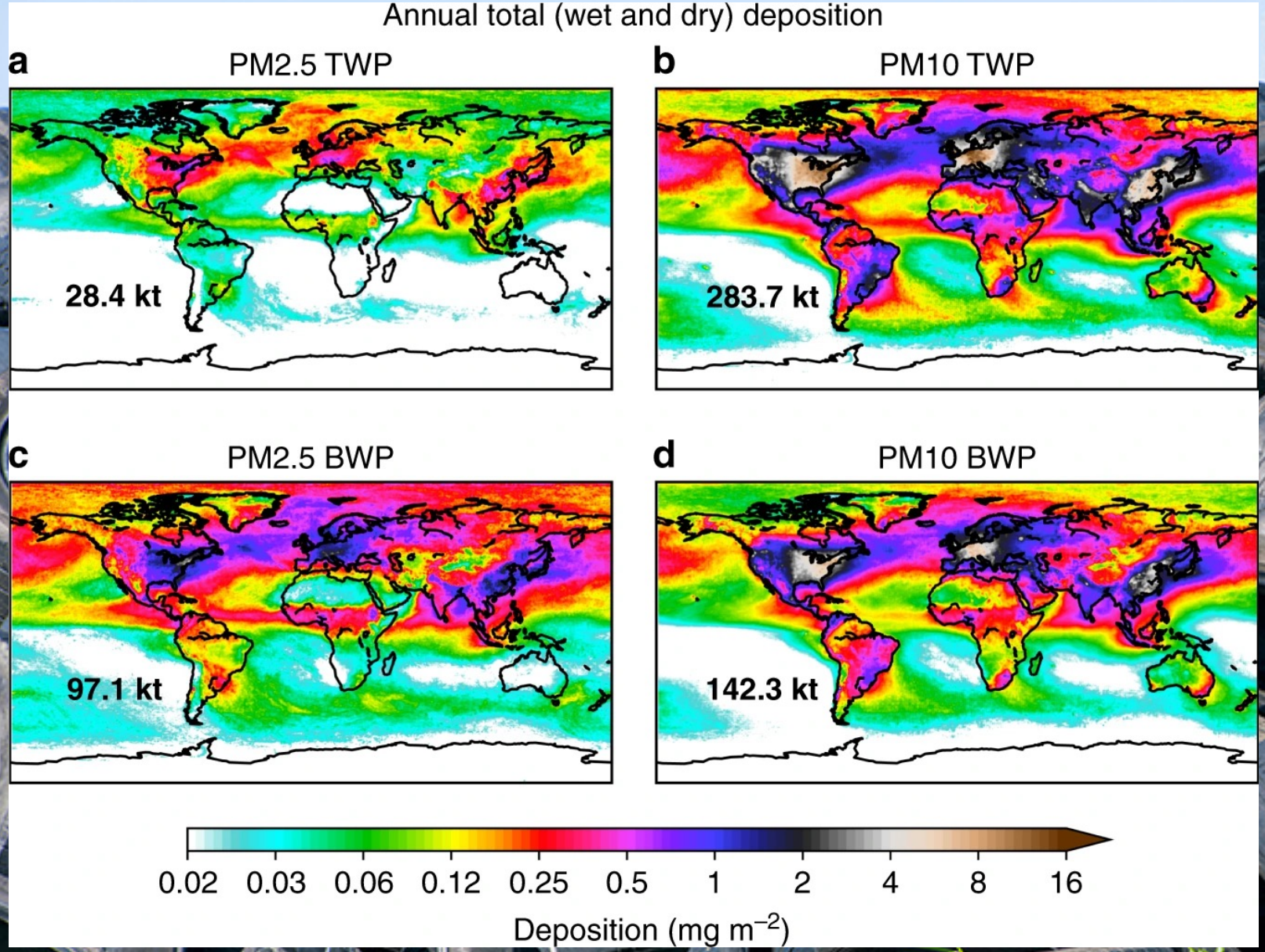
- Particles from brake wear, tyre wear and road surface wear currently constitute 60% and 73% (by mass), respectively, of primary PM2.5 and PM10 emissions from road transport (UK National Atmospheric Emissions Inventory)
- Will become more dominant in the future.
- Contribute 7.4% and 8.5% of all UK primary PM2.5 and PM10 emissions.

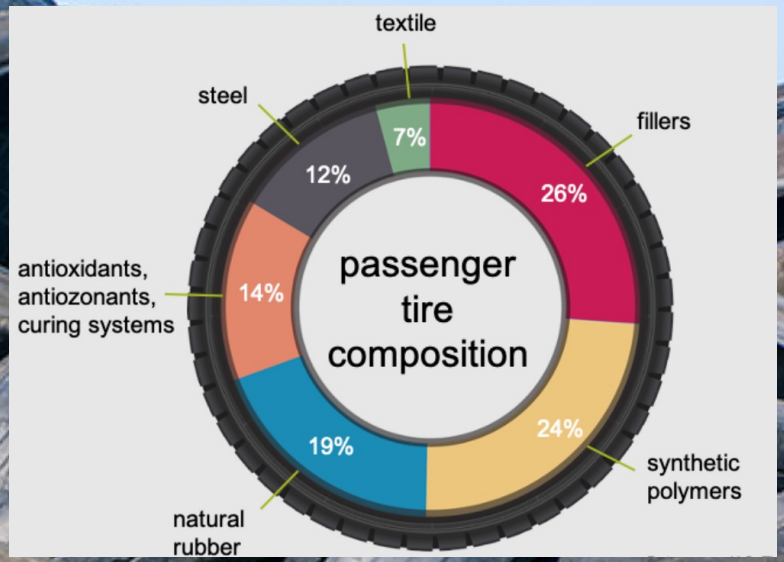
AQEG 2019

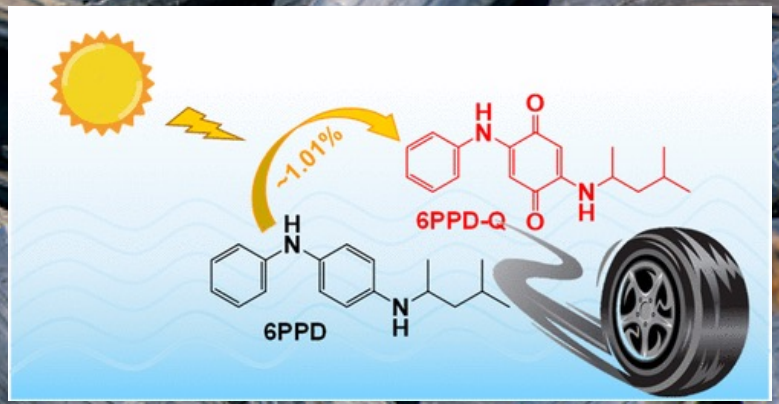




Tan et al., 2023





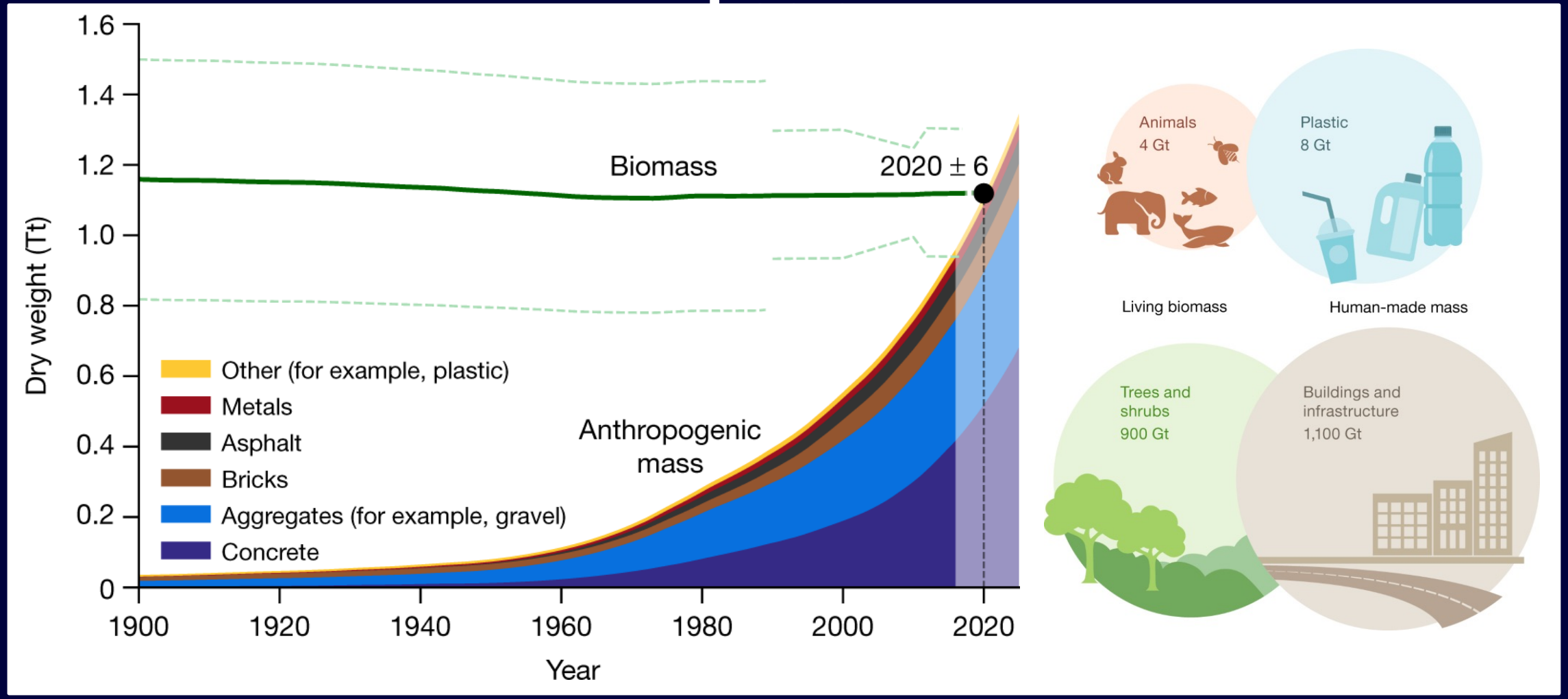


Evangeliou et al., 2020

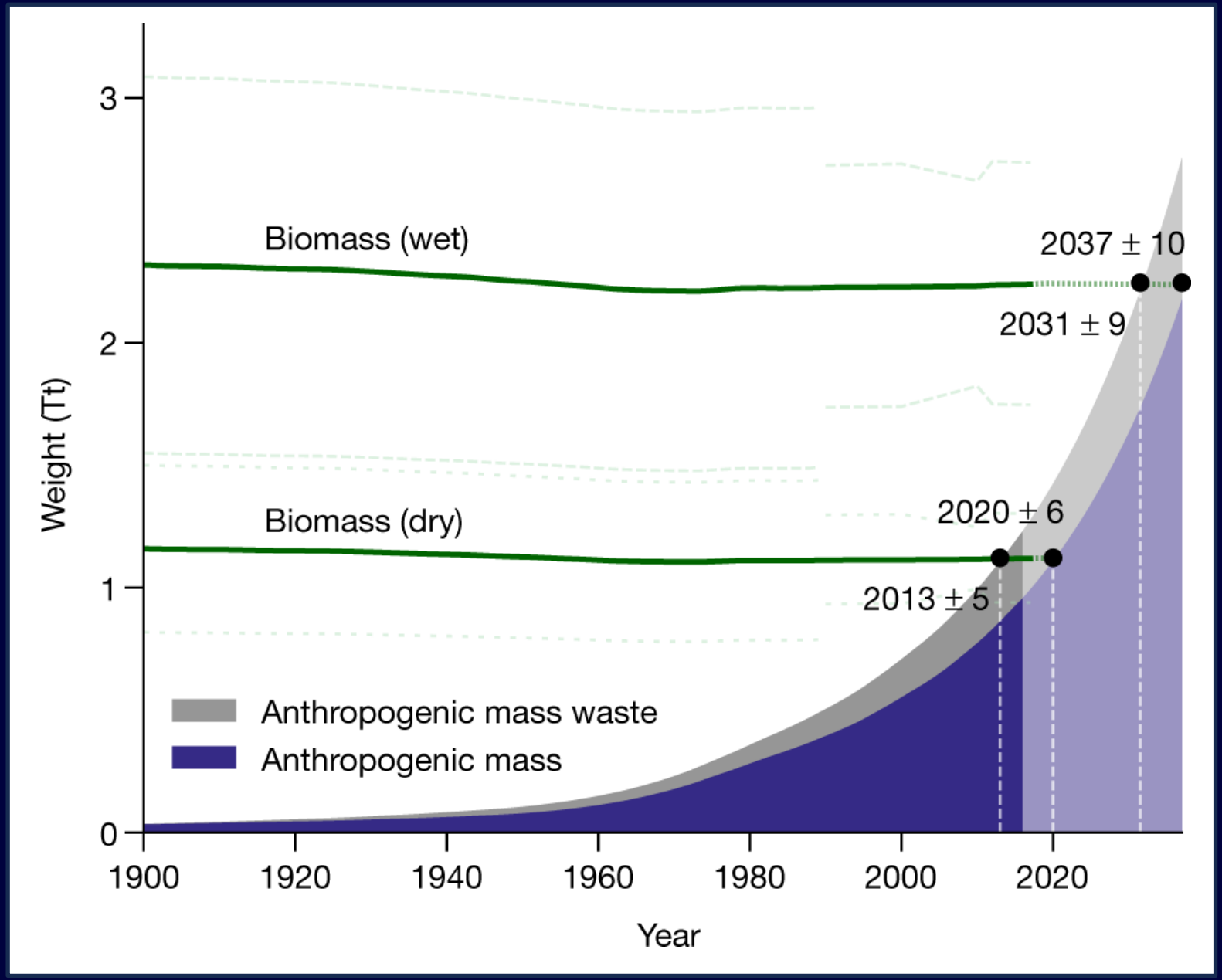
Environ. Sci. Technol. Lett. 2023, 10, 9, 798–803

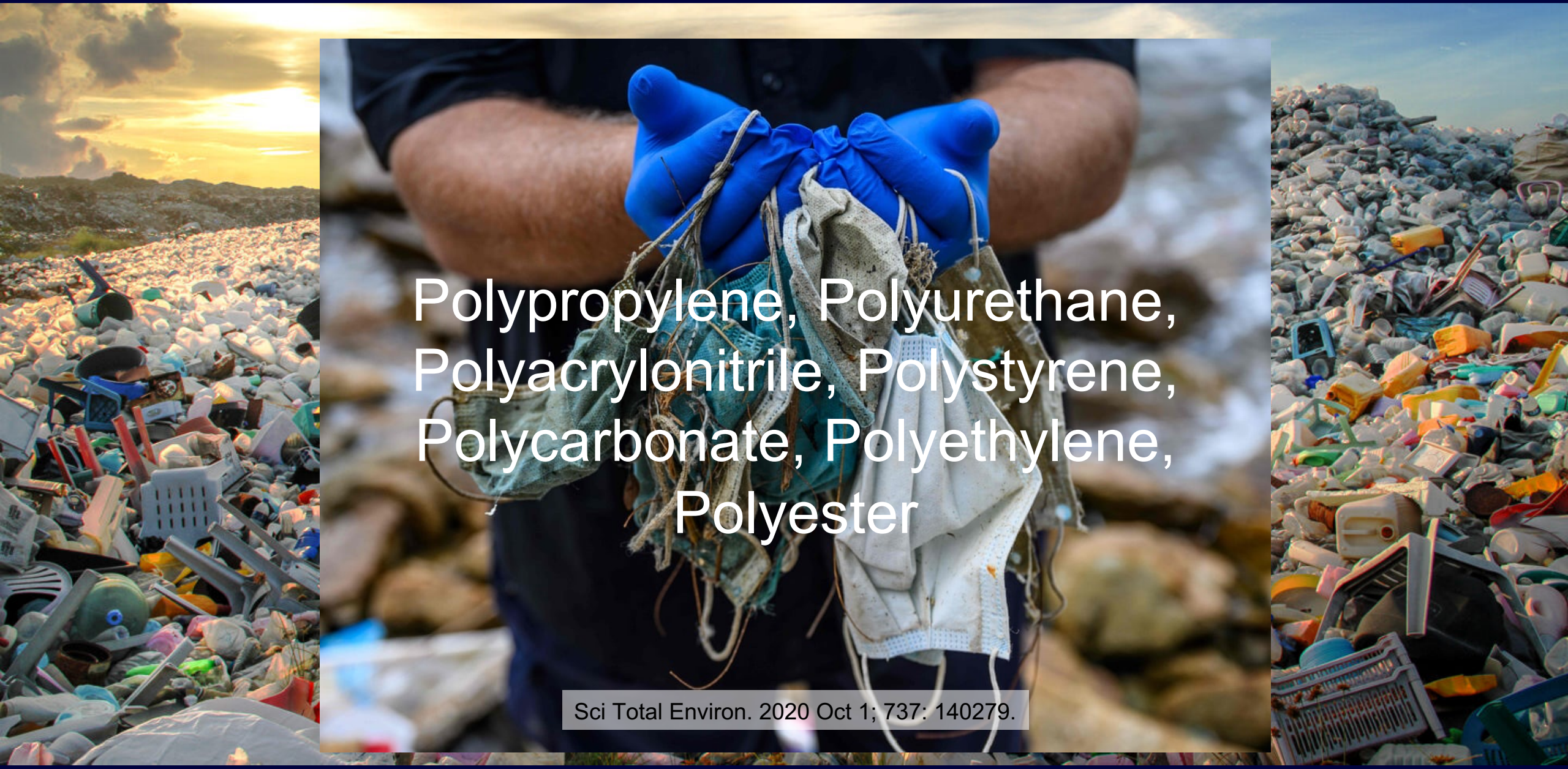
Context

Biomass and anthropogenic mass estimates since the beginning of the twentieth century on a dry-mass

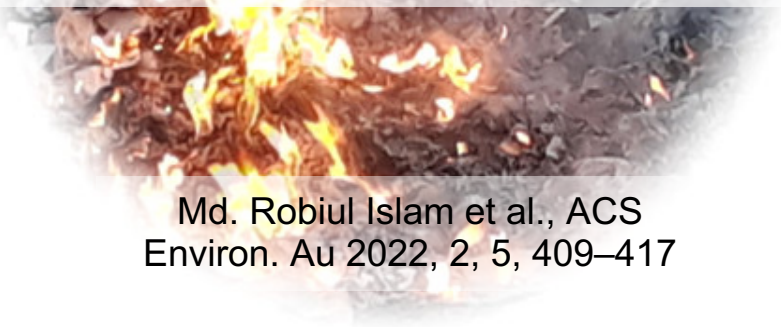


Elhacham, E., Ben-Uri, L., Grozovski, J. et al. Global human-made mass exceeds all living biomass. Nature 588, 442–444 (2020). https://doi.org/10.1038/s41586-020-3010-5


Biomass (wet)
2037 ± 10
2031 ± 9
Biomass (dry)
2020 ± 6
2013 ± 5
Anthropogenic mass waste
Anthropogenic mass
Weight (Tt)
Year
0
1
2
3
1900
1920
1940
1960
1980
2000
2020

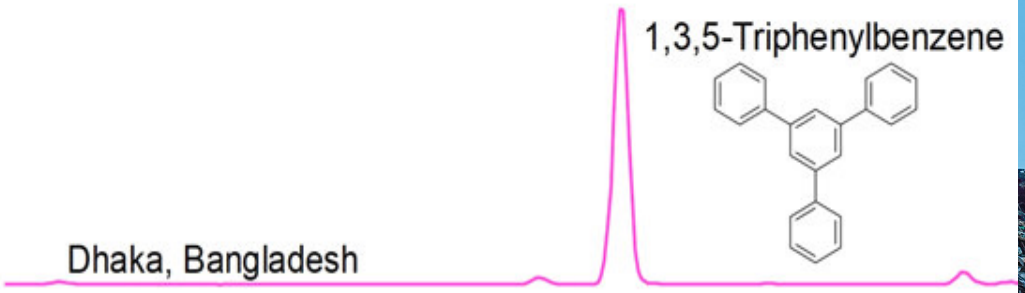

Polypropylene, Polyurethane,
Polyacrylonitrile, Polystyrene,
Polycarbonate, Polyethylene,
Polyester
Sci Total Environ. 2020 Oct 1; 737: 140279.

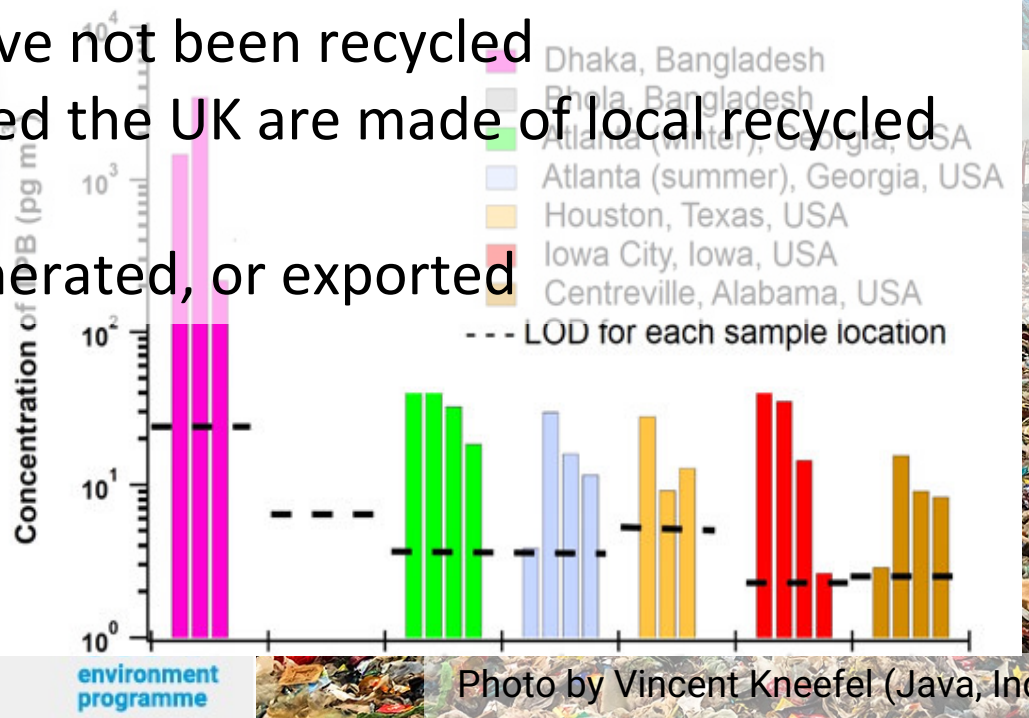
Plastic burning impacts on air quality



- 91% of all plastics produced have not been recycled
- Less the 3% of plastics consumed the UK are made of local recycled plastics
- Most ends up in landfill, is incinerated, or exported

Md. Robiul Islam et al., ACS Environ. Au 2022, 2, 5, 409–417





EXTRACTION
and processing
raw materials

DISPOSAL
Open-burning of p
waste can release
chemicals such as
and furans

Photo by Muhammad Amdad Hossain (Chittagong, Bangladesh)

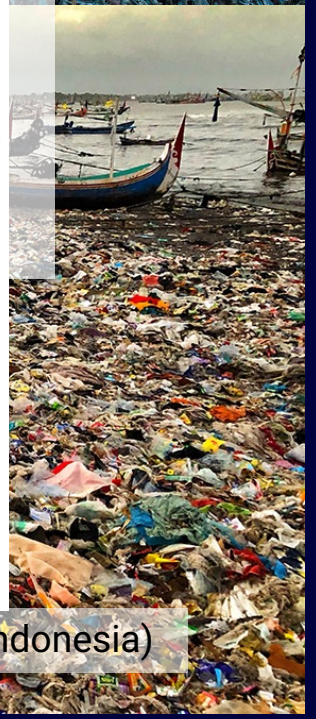
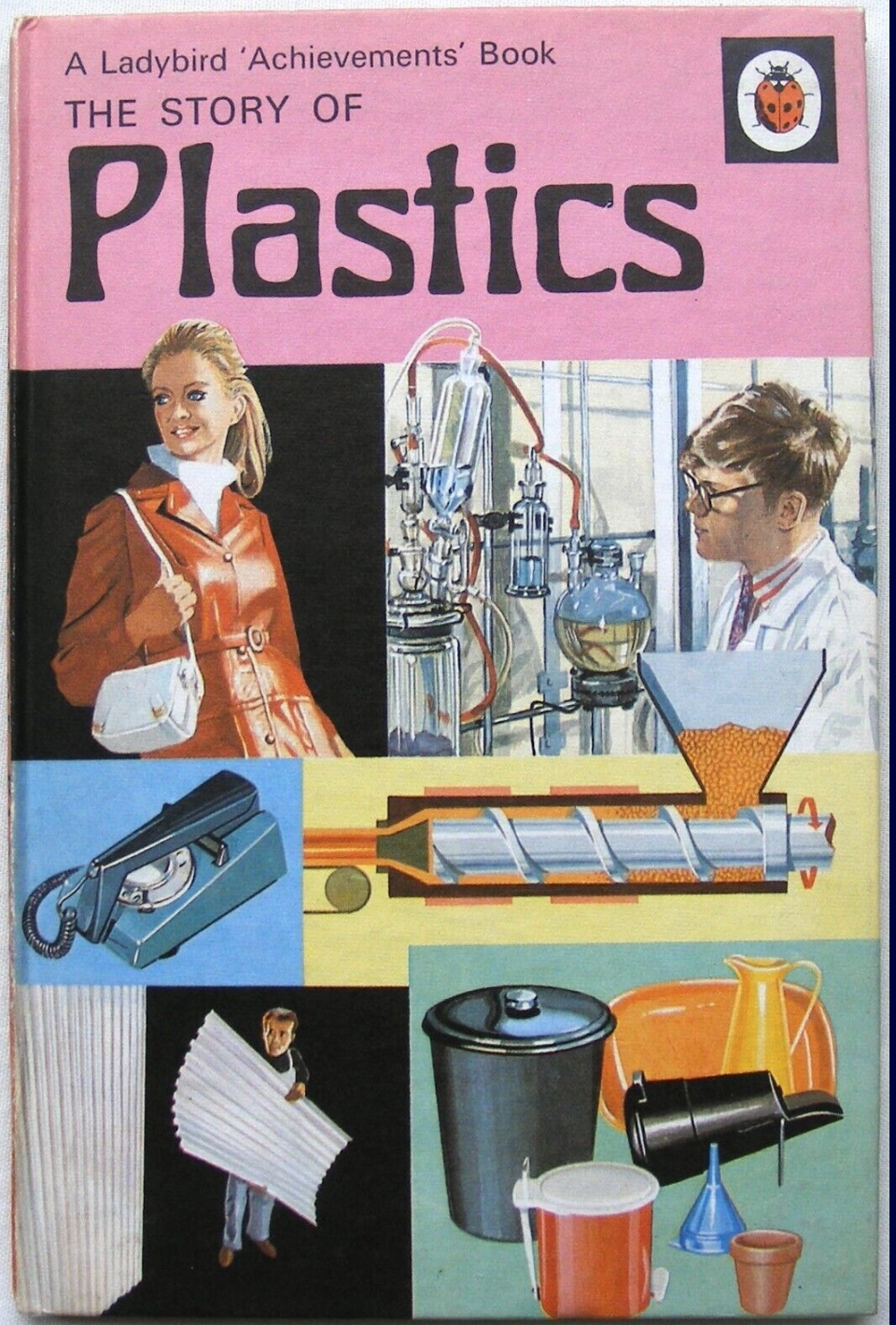
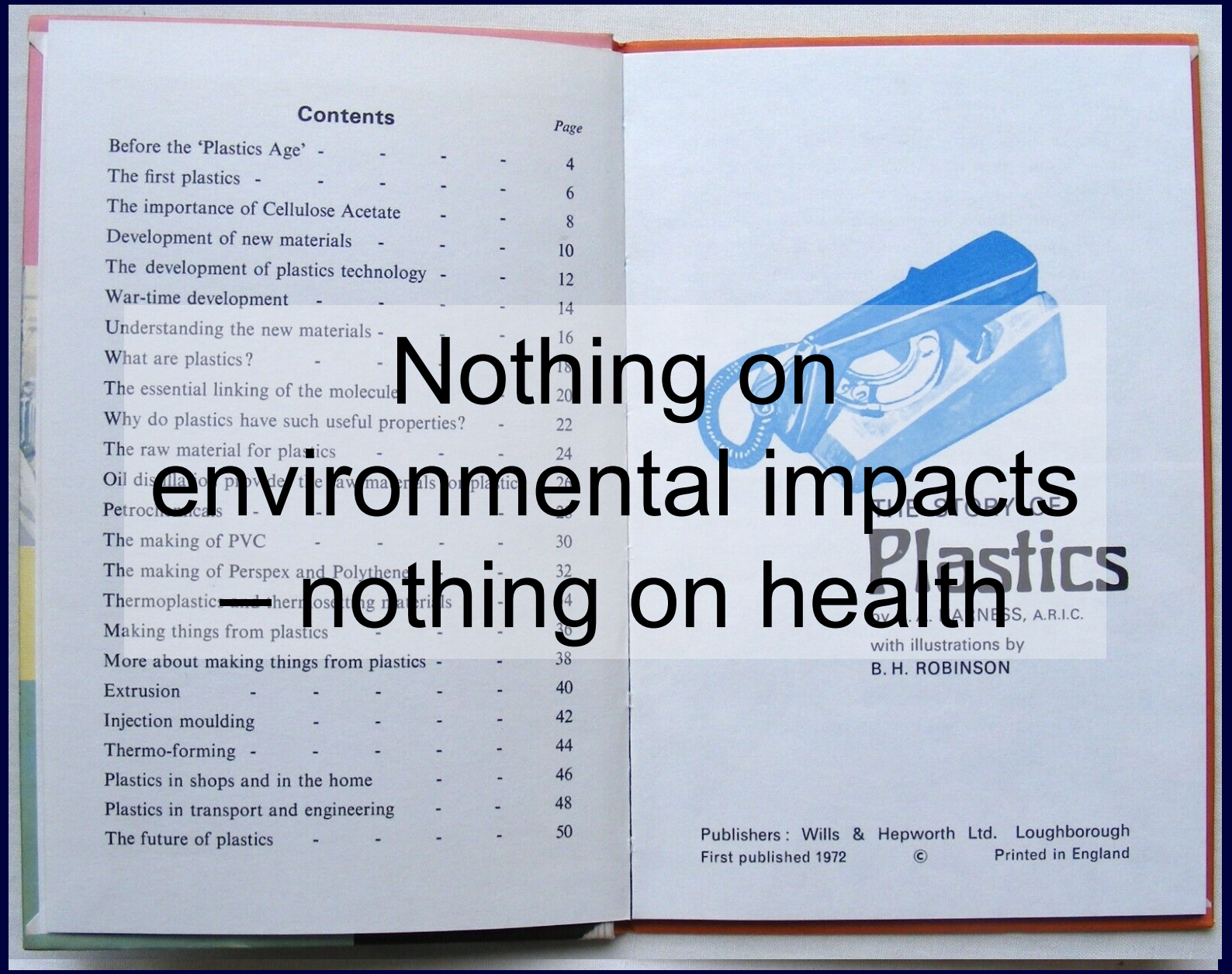


Photo by Vincent Kneefel (Java, Indonesia)





Contents

THE STORY OF
Plastics

W. J. HARNESS, A.R.I.C.
with illustrations by
B. H. ROBINSON

Publishers: Wills & Hepworth Ltd. Loughborough
First published 1972 © Printed in England

Nothing on environmental impacts — nothing on health

Solutions & untoward consequences

Precautionary princple


Daily Mail

THURSDAY, AUGUST 25, 2016 www.dailymail.co.uk DAILY NEWSPAPER OF THE YEAR 65p

BAN THE TOXIC BEADS NOW!

Tiny plastic beads in everything from shower gel to toothpaste are poisoning oceans and threatening health. Today we call for them to be outlawed

REVEALED: THE TOXIC BEADS IN YOUR FOOD

August 26

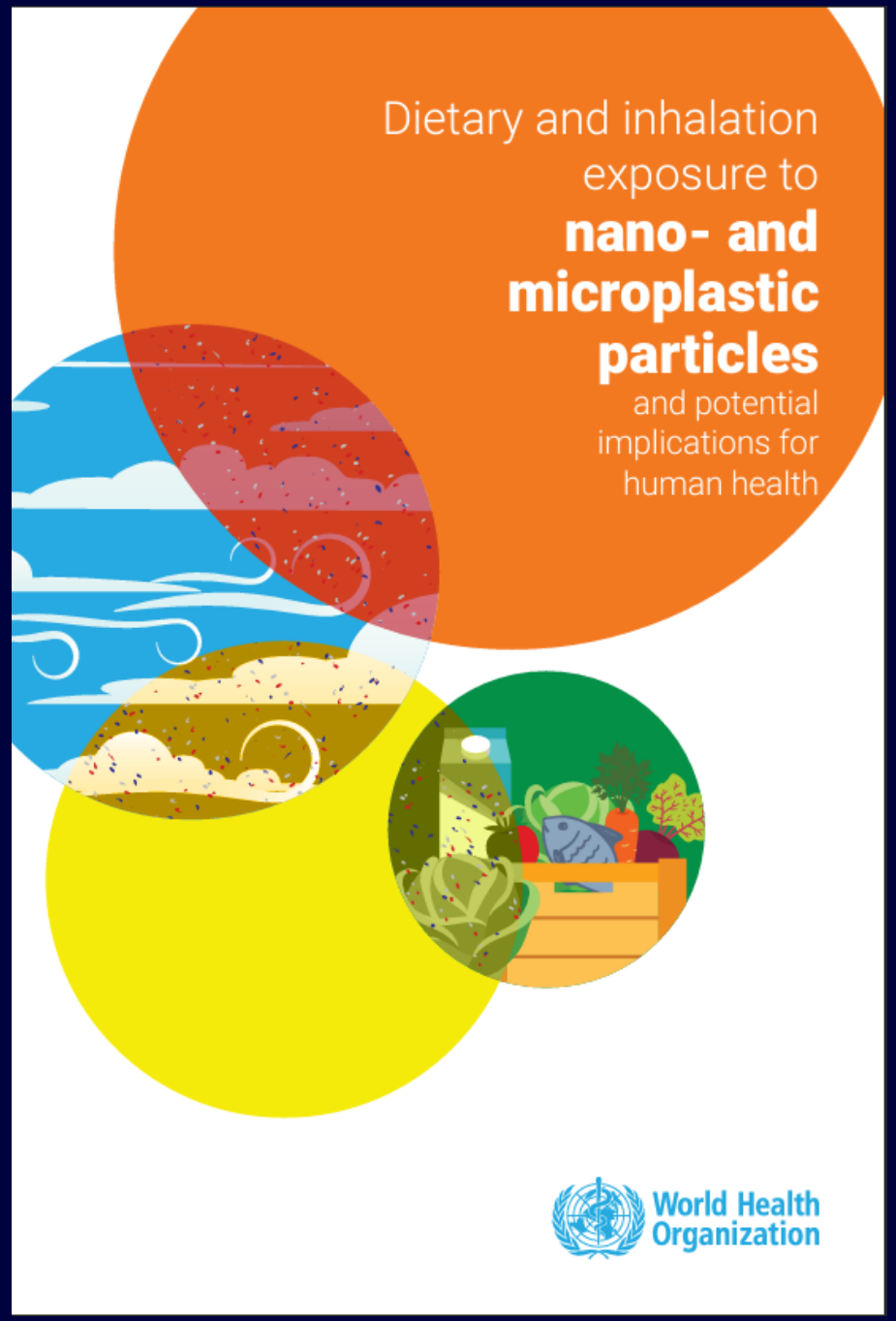
Microbead toxins could enter human tissue say experts

"Microbeads might be tiny, but they are lethal to sea creatures and entirely unnecessary. We have led the way in banning these toxic pieces of plastic, but this is by no means the end of our fight".

Rt Hon Michael Gove MP
Secretary of State for Environment, Food and Rural Affairs

25 YEAR PLAN | Department for Environment Food & Rural Affairs

Conculsion


Dietary and inhalation exposure to
nano- and microplastic particles
and potential implications for human health
World Health Organization


UN environment programme
CHEMICALS IN PLASTICS
A TECHNICAL REPORT
CONVENTIONS