

SCIENTIFIC CHALLENGES OF PLASTIC POLLUTION IN THE MARINE ENVIRONMENT: THE ROLE OF 'IMPERFECT' DEFINITIONS



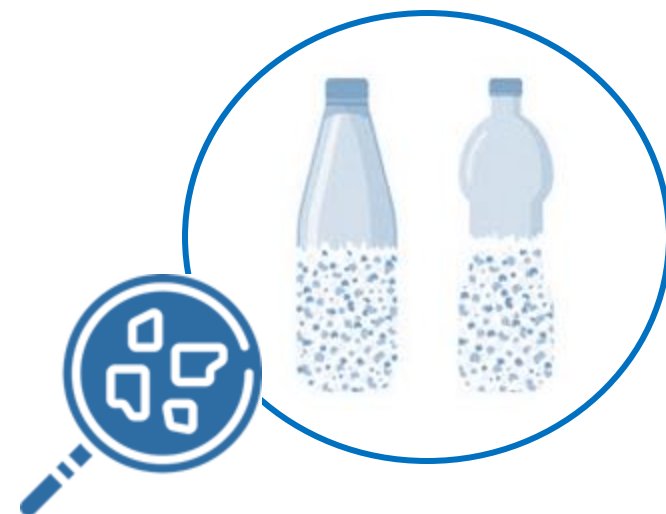
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MICROPLASTICS: MAIN CHALLENGES

UNITED
NATIONS

EP

UNEP/EA.5/Res.14



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United Nations
Environment Assembly of the
United Nations Environment
Programme

United Nations Environment Assembly of the
United Nations Environment Programme
Fifth session
Nairobi (hybrid), 22 and 23 February 2021
and 28 February–2 March 2022

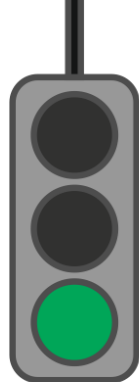
Resolution adopted by the United Nations Environment
Assembly on 2 March 2022

5/14. End plastic pollution: towards an international legally binding instrument

- Widespread uncontrolled distribution.
- Increase in unknowing human consumption. Microplastics (5-10 microns) have been detected in human placenta, feces, and blood.
- Lack of fundamental information on hazardous concentrations of microplastics consumption/accumulation in humans and size effects.
- Need to develop regulations for the detection and characterisation of microplastics in the environment and biological systems.
- Consolidation of the global community and development of an international legally binding agreement to limit the spread of polymer waste (2022).



Herman Shtaudinger
(Über Polymerisation.
Europ. J. of Inorg.
Chem. 53, 1073-1085,
1920) and his Lab in ETH



POLYMERS

For many years, scientists have been looking for materials that are cheap, lightweight, stable and inert.

Such materials, namely *polymers*, have been mass produced since the early 1950s. Between then and now, *their production has increased by over 200 times*. However, over the same period the Earth's *population has more than tripled*.

Polymers, or *macromolecular compounds*, represent very long molecules consisting of repeating units (monomers) attached to a chain (Noble Prize to Herman Staudinger in 1953).

Synthetic polymers have taken a strong leading position in the hierarchy of modern materials, and have become indispensable in people's lives.

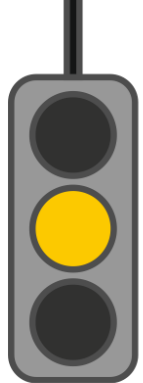
Among the calls of environmental activists, we can find incorrect, alarming definitions of plastics:



ETH zürich



↑ Nairobi, 2023, INC-3, Side Event 5:
Plastics = Carbon + Chemicals (mostly EDCs)



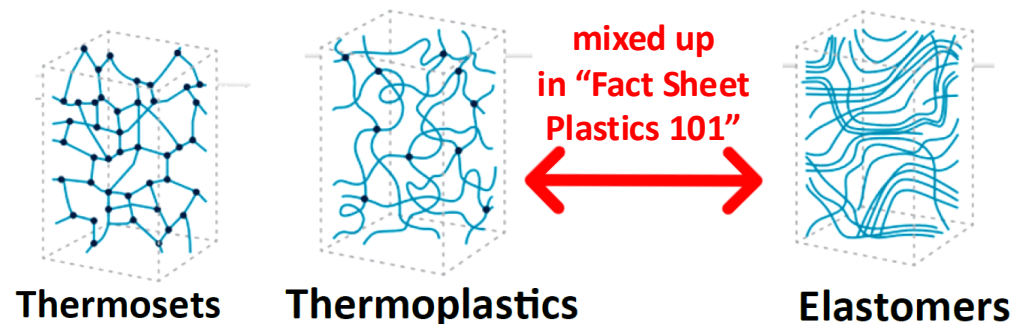
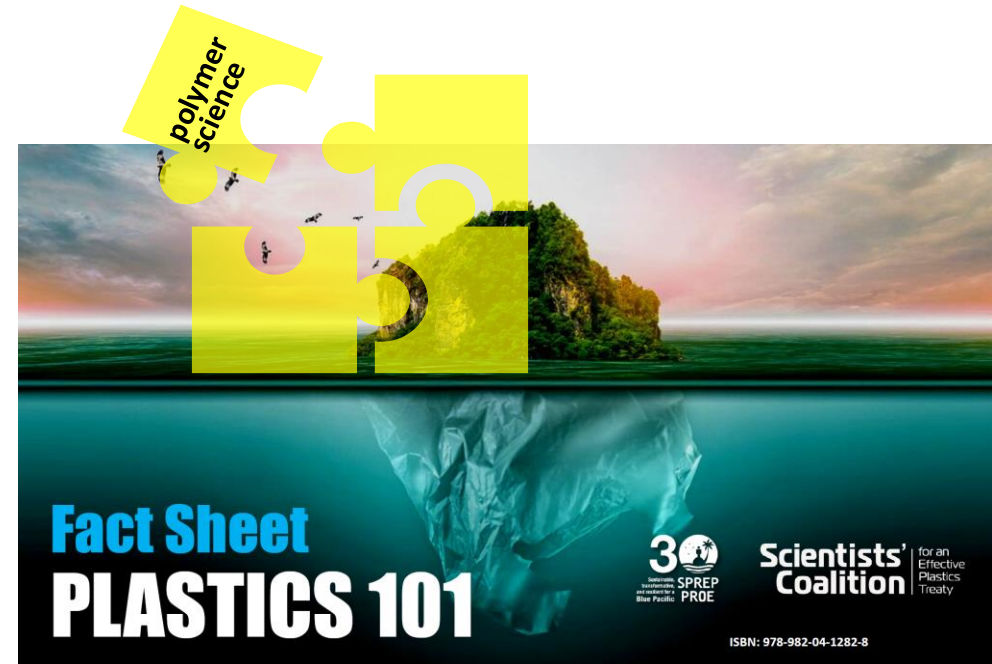
WHAT ARE PLASTICS: errors in definitions

The term Plastic(s) for the aim of a future legally binding instrument originated mainly in *environmental science* and **is not included in the IUPAC book of chemical terms** (IUPAC Gold Book).

Environmental scientists do not specify **which type of polymers** are covered by the term *plastics*, and generally consider all *synthetic polymers* as plastics, although some natural polymers (e.g., natural rubber before vulcanisation) are characterized as having plasticity.

Natural polymers based on proteins (**wool, silk**) are **never considered as plastics**. However, small particles of cellulose (**natural polymers**) and its derivatives are sometimes considered as microplastics, and account for up to 30% of the microplastics found in the Arctic.

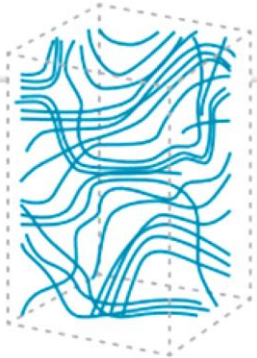
A. Lusher et al, *Scientific Reports* **2015** 5:14947.



Lack of specialized knowledge often leads to errors: thermoplastics are confused with elastomers and *vice versa* in “Fact Sheet PLASTICS 101” distributed before INC-3 by Scientists' Coalition.

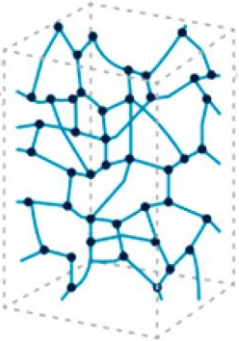
BASIC PROPERTIES OF MAIN TYPES OF POLYMERS

Plastics



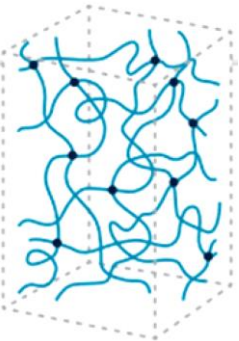
Thermoplastics (i.e. true plastics or *plastic polymers*)

non-crosslinked polymers,
repairable, wide recycling possibilities, amorphous or semi-crystalline



Thermosets

highly cross-linked polymers



Elastomers

slightly cross-linked polymers

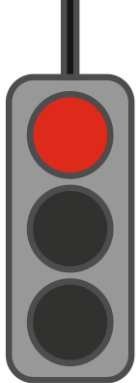
Cross-linked polymers,
their particles do not dissolve.

Cross-linking leads to reduced repairability and recyclability.



A separate problem:
FATE of polymer composites
(not enough attention)





FATE OF PLASTIC PRODUCTS



MODEL 2023: Banning polymer production does not solve the general problem of plastic waste

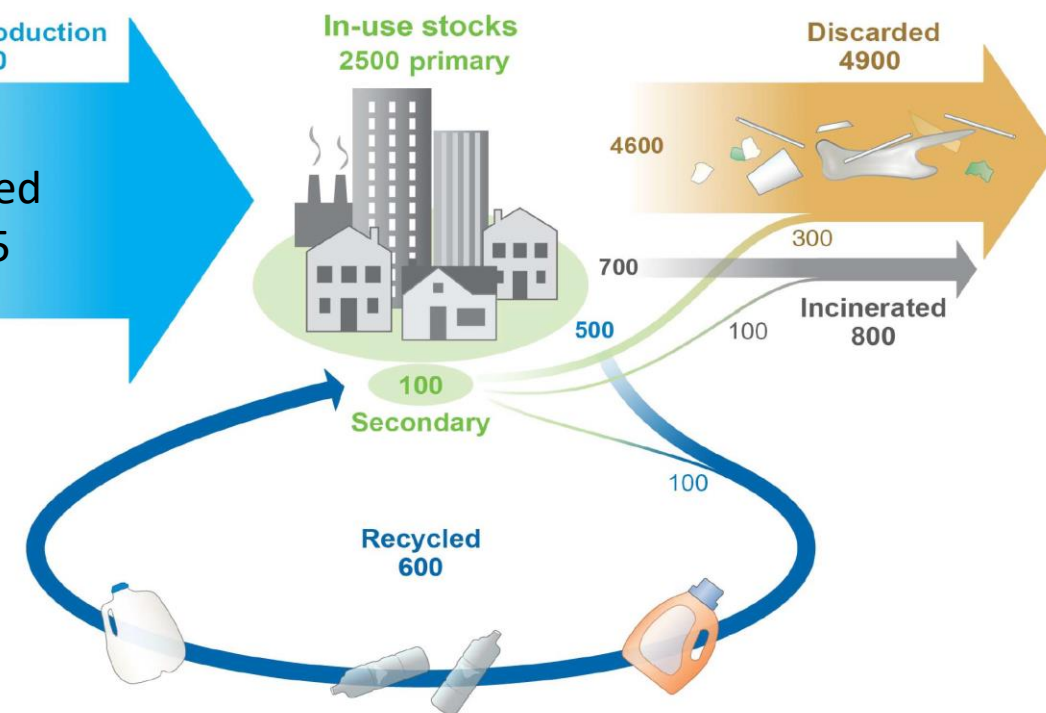
A.E. Schwarz et al. *Science of the Total Environment* **2023**, 875, 162644

Already existing plastic waste is a major source of uncontrolled macro- and microplastics input in the environment

MODEL 2017:

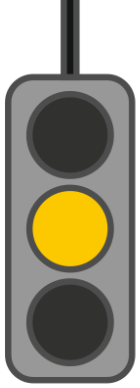
Primary production
8300

Plastics
produced
by 2015



Geyer, Jambeck, Law. *Science Advances* **2017**; 3: e1700782

Less than 8% of plastic waste are recycled, and about 1.5% are recycled more than once



LANGUAGE DIFFERENCES CAN LEAD TO CLASSIFICATION ERRORS

Commercial plastics are known as *resins* in *North America*. In *some other countries*, a word with the same pronunciation means *elastomers*.

ISO: International Organization for Standardization

According to ISO 472:

A plastic is any material which contains as an essential ingredient a high polymer, and which, at some stage in its processing into a finished product, can be shaped by flow.

Note: *Elastomeric materials*, which are also shaped by flow, are not considered to be plastics.

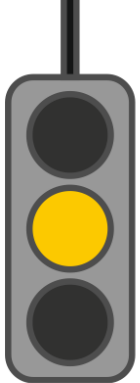


Standards Sectors About ISO News Taking part

ISO 472:2013/Amd 1:2018

Plastics

Vocabulary



MICROPLASTICS: PROBLEMS WITH SIZE DEFINITION

U.S. National Oceanic and Atmospheric Administration (NOAA), 2009

Definition of microplastics. The Workshop participants defined microplastics as plastic particles smaller than 5mm.

ISO 24187, 2023

microplastic

any solid plastic particle insoluble in water with dimension between $1\text{ }\mu\text{m}$ and $1\,000\text{ }\mu\text{m}$ (= 1 mm)

European Chemicals Agency (ECHA), 2020

‘microplastic’ means particles containing solid polymer, to which additives or other substances may have been added, and where $\geq 1\%$ w/w of particles have (i) all dimensions $0.1\text{ }\mu\text{m} \leq x \leq 5\text{ mm}$, or (ii) a length of $0.3\text{ }\mu\text{m} \leq x \leq 15\text{ mm}$ and length to diameter ratio of >3 .



MP: absence of an official definition

MICROPLASTICS:



MAR. 3, 2025

A scientific approach for microplastic definition

SERGEY LYULIN Polymer Scientist,
Member of the Russian delegation in Intergovernmental Negotiating Committee (INC) to develop an international legally binding instrument on plastic pollution; Head of laboratory in Microplastics Advanced Research Center, Veliky Novgorod, Russia; Head of Department of Chemistry of Highmolecular Compounds in St. Petersburg State University, St. Petersburg, Russia.

ANDREY GURTOVENKO Polymer Scientist,
Head of Laboratory, Saint-Petersburg and Veliky Novgorod, Russia

JOSE KENNY Polymer Scientist,
President of European Center of Nanostructured Polymers, Terni, Italy;
Head of Microplastics Advanced Research Center, Veliky Novgorod, Russia.

This eLetter addresses a serious mistake in a recent review by R. Thompson et al.,
“Twenty years of microplastic pollution...

[view more](#)

Humans produce large quantities of synthetic polymers from fossil fuels. Due to low cost, large quantities of plastic are disposed of uncontrollably. Tiny plastic particles (<5 mm) – microplastics – are formed during degradation of macroplastics.

R. THOMPSON'S CLASSIFICATION OF MICROPLASTICS (6 TYPES):

Primary microplastics

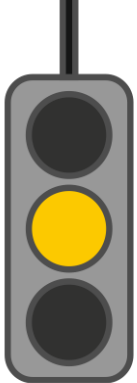
1. Primary plastic pre-production materials, e.g., pellets, flakes, and powders
2. Primary microplastics used directly as small pieces e.g., glitter, confetti
3. Primary microplastics intentionally added to another product e.g., microbeads in cosmetics, **pigments in paint** (error!)

Secondary microplastics

1. Secondary microplastics (≤ 5 mm) generated by wear of products during use e.g., tires, textiles, cleaning painted surfaces
2. Secondary microplastics (≤ 5 mm) generated in waste management e.g., during recycling
3. Secondary microplastics (≤ 5 mm) generated by breakdown of larger items in the environment



R. Thompson et al. *Twenty years of microplastic pollution research—what have we learned?* *Science*, 2024, 386(6720)

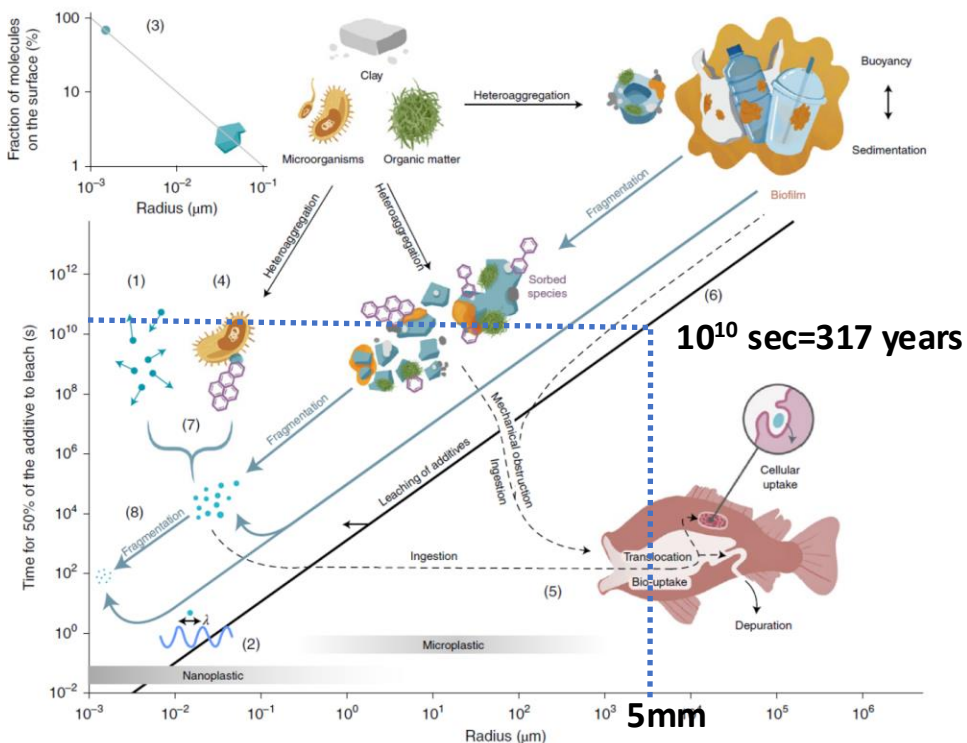


MICROPLASTICS VS. NANOPLASTICS

**Nanoplastics are neither microplastics
nor engineered nanoparticles**

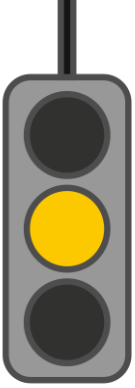
J. Gigault, H. El Hadri, B. Nguyen, B. Grassl,
L. Rowenczyk, N. Tufenkji, S. Feng, M. Wiesner

Nature Nanotechnology | VOL 16 | 2021 | 501–507

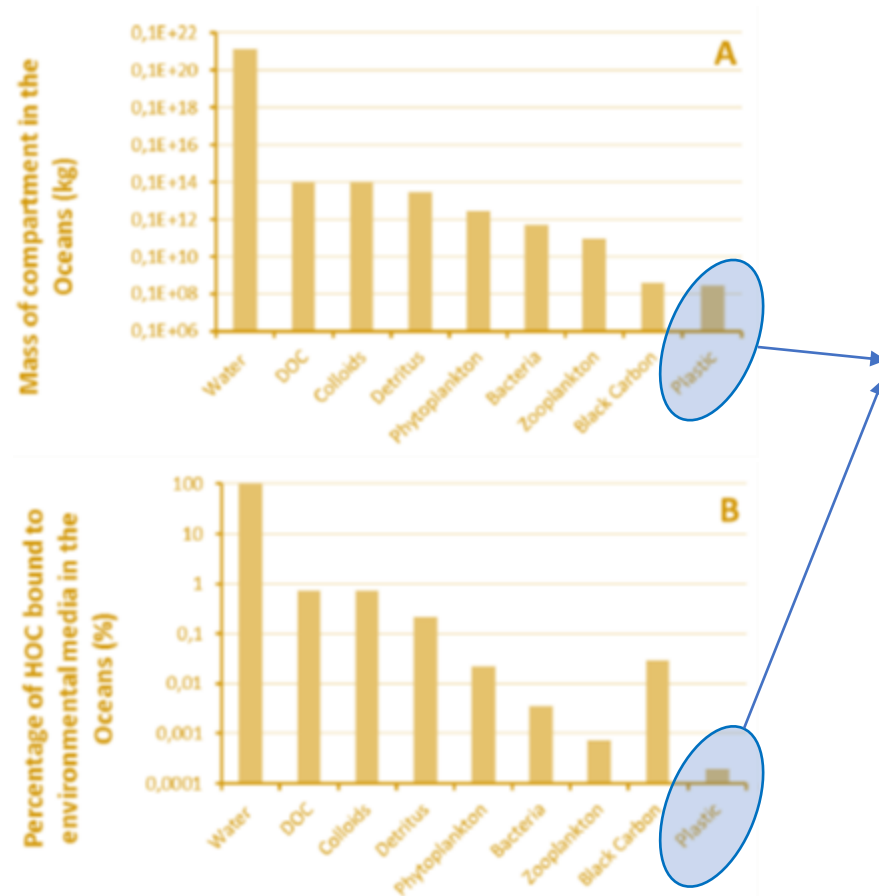


REASONS FOR THE DIFFERENCE BETWEEN NANOPLASTICS AND MICROPLASTICS

1. The predominance of Brownian (random) motion over sedimentation and buoyancy in suspension.
2. Deviation from the ray approximation of the interaction between light and polymer. For microplastics, the interaction with light can be approximated by representing light as a straight ray. For nanoplastics, the wavelike nature of light is important.
3. A high fraction of polymer molecules on the surface of the particle, leading to a higher contribution of surface interactions.
4. Particle size is small compared to the size of microorganisms but can be comparable to the size of environmental macromolecules, leading to their active adsorption on the surface.
5. Size permitting bioabsorption, translocation and transport across biological membranes.
6. Small size and large surface fraction accelerate diffusive release of additives (**300 years for 5mm in size and several seconds for nm size scale**).



MICROPLASTICS: KEY PROBLEMS



- The dangers of microplastics to human health have not been proven
- Until 2017, it was believed that the world's oceans are the main "accumulator" of microplastics. However, the annual **pollution of soils** by MP is estimated to be 4-23 times higher than that for the oceans. [Sci. Total Environ. 2017, 586, 127–141.](#)
- **MP as a carrier of hazardous pollutants have significantly less impact relative to other types of natural carriers.** The fraction of total hydrophobic pollutants sorbed by plastics in the ocean is estimated to be tens of thousands of times smaller than the fraction sorbed by other types of particles in the ocean (such as *dissolved organic carbon, phytoplankton, zooplankton, bacteria, black carbon*, etc.)
[Environ. Sci. Technol. 2016, 50, 3315–3326](#)
- An **interdisciplinary approach** to the MP research problem is urgently needed

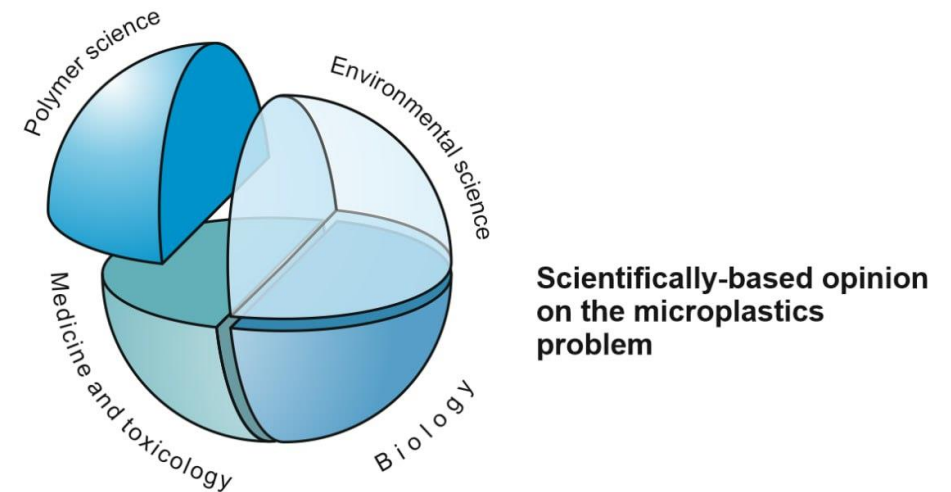
PLASTIC POLLUTION TREATY: the role of scientific combined efforts

Research and treatment of microplastic pollution requires more chemists, especially polymer scientists, to participate in order to better solve the problem of plastic pollution.

We should highlight fundamental aspects regarding the role of polymer science in the behavior of MPs and in understanding the effects of MPs on the environment and on the health of humans and other living species.

The most important areas for the plastic waste and microplastics problem, which can be solved only through the combined efforts of all experts, including polymer scientists:

1. nomenclature and terminology,
2. MP's identification and characterization,
3. fragmentation mechanism,
4. environmental fate and transport,
5. risk assessment,
6. remediation and alternative solutions



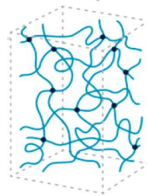
S.Lyulin, A.Gurtovenko, F.Saliu, P.Galli, D.Surroop, A.Yaroslavov, S.Radionova, T.Kuznetsova, J.Kenny. *Microplastics in the environment: the role of polymer science*. *Science of the Total Environment*, 998 (2025) 180267.

1. Nomenclature and terminology

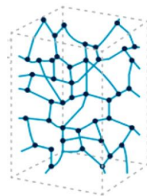


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Elastomers – are slightly cross-linked polymers

Cross-linking leads to reduced repairability and recyclability.

According to ISO 472: **A plastic** is any material which contains as an essential ingredient a high polymer, and which, at some stage in its processing into a finished product, can be shaped by flow. **Note:** *Elastomeric materials*, which are also shaped by flow, **are not considered to be plastics.**

Terms "plastic" and "microplastic" should be included in the International Union of Pure and Applied Chemistry (IUPAC) **Gold Book** of chemical terms

Science

MAR. 3, 2025

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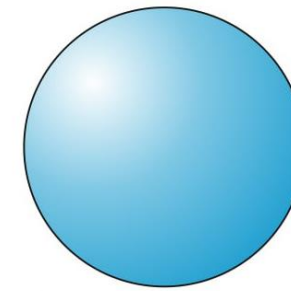
S. Lyulin, A. Gurtovenko, J. Kenny
A scientific approach for microplastic definition
Science,
2025-03-03 | eLetter
<https://www.science.org/doi/10.1126/science.adl2746>

2. MP's identification and characterization

Scientists can develop and refine analytical methods to distinguish between different plastic types, additives, and degradation products.

3. Fragmentation mechanism

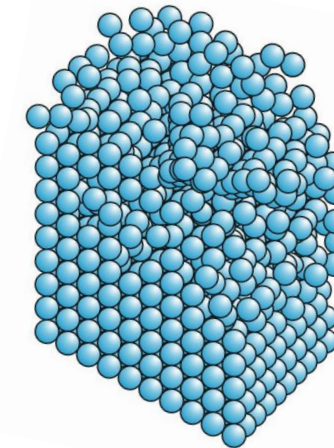
Despite attempts to develop predictive models, the rate at which macroplastic fragments into MPs, or MPs degrade into nanoplastics, remains uncertain. This unpredictability complicates estimating the timescales required for plastics to mineralize



$$D=1 \text{ mm} \quad n=1$$

$$V = \pi D^3/6 \approx 0.52 \text{ mm}^3$$

$$S = \pi D^2 \approx 3.14 \text{ mm}^2$$



$$n=1000 \quad D=0.1 \text{ mm}$$

$$V = 1000 \times \pi D^3/6 \approx 0.52 \text{ mm}^3$$

$$S = 1000 \times \pi D^2 \approx 10 \times 3.14 \text{ mm}^2$$

4. Environmental fate and transport



PlastChem project suggested “**Red list**” of additives includes:

- **silicon oxide;**
- **ozone;**
- **metal oxides**

Thursday 16 October

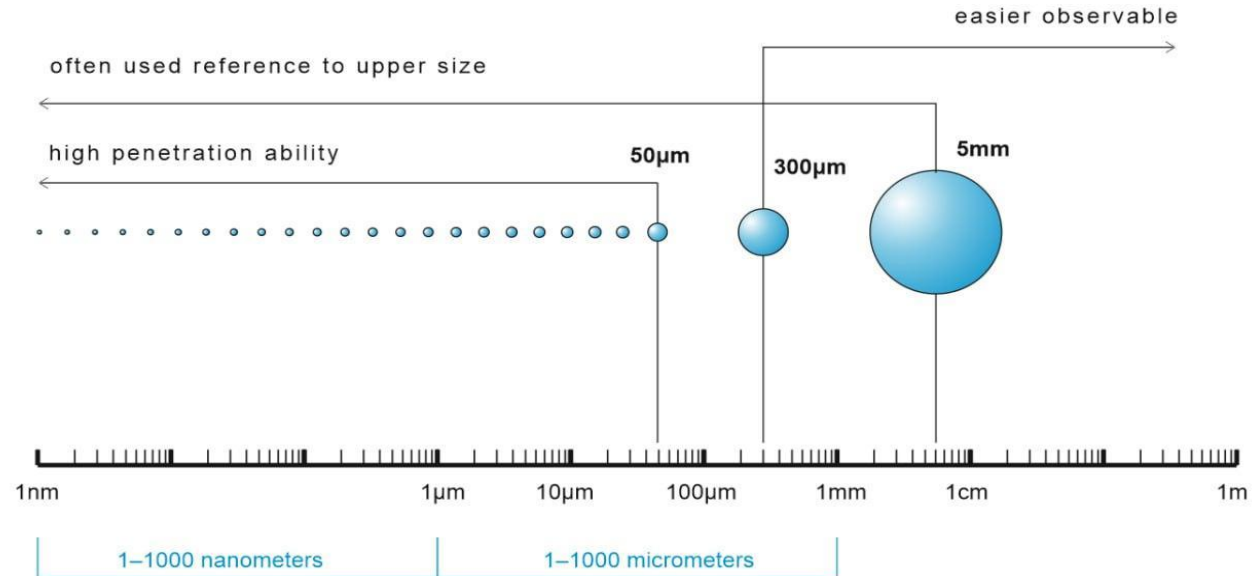


16:50 – 17:10

Plastic additive chemicals: A critical review of the PlastChem report

5. Risk assessment

The problem in the MP size definition: the potential hazards of small-sized MPs are extended to larger particles in an easily observable range ($300\mu\text{m} < \text{MP} < 5\text{mm}$).



Since partitioning influences MPs' capacity to act as carriers for other environmental contaminants and toxic pollutants, it is essential **to compare MP-related risks** with those posed by dissolved pollutants and pollutants adsorbed onto other relevant marine particulate components.

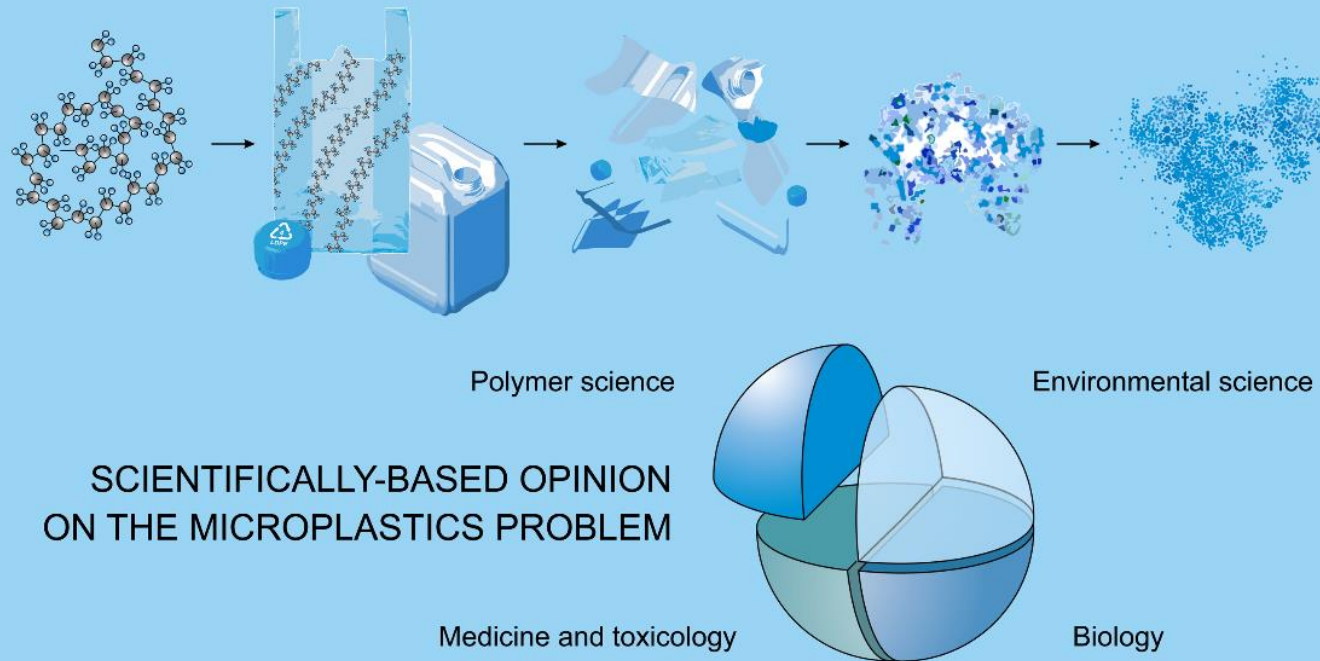
6. Remediation and alternative solutions

Developing alternative materials with improved degradability, reduced environmental impact, and minimal additives content is essential to reduce the environmental burden of plastics

1. Instead of reducing polymer use, our efforts should focus on developing multidisciplinary scientific strategies for **proper design and recycling** of plastic products, and responsible governmental regulations.
2. Only the combined efforts of all experts, *including environmental and polymer scientists*, can solve the problem of plastic waste and microplastics. There is an urgent need for the **establishment of an influential interdisciplinary scientific council** to achieve this goal.



Scientists' declaration
on current approaches
to plastics and plastic
-containing materials,
considering all stages
of their life cycle



More info about Scientists' declaration
www.microplastics.pro

INTERNATIONAL CONFERENCE “MICROPLASTICS IN POLYMER SCIENCE”

The 3rd Conference will be held on October 20-24, 2025, in Samarkand, Uzbekistan and will bring together scientists from various fields involved in microplastics research



Chairman:
Sergey Lyulin



The topics:



Modelling in microplastic research



Analysis and characterization of microplastics



Microplastics in environmental and Earth sciences



Microplastics in biology, pharmacology, and medicine

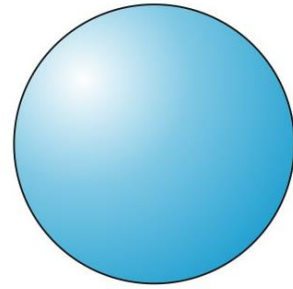


Research and industrial strategies for the prevention and reduction of microplastics pollution, including plastics recycling and development of biodegradable polymers



www.microplastics.ru
More info about the conference!





THANK YOU FOR YOUR ATTENTION!