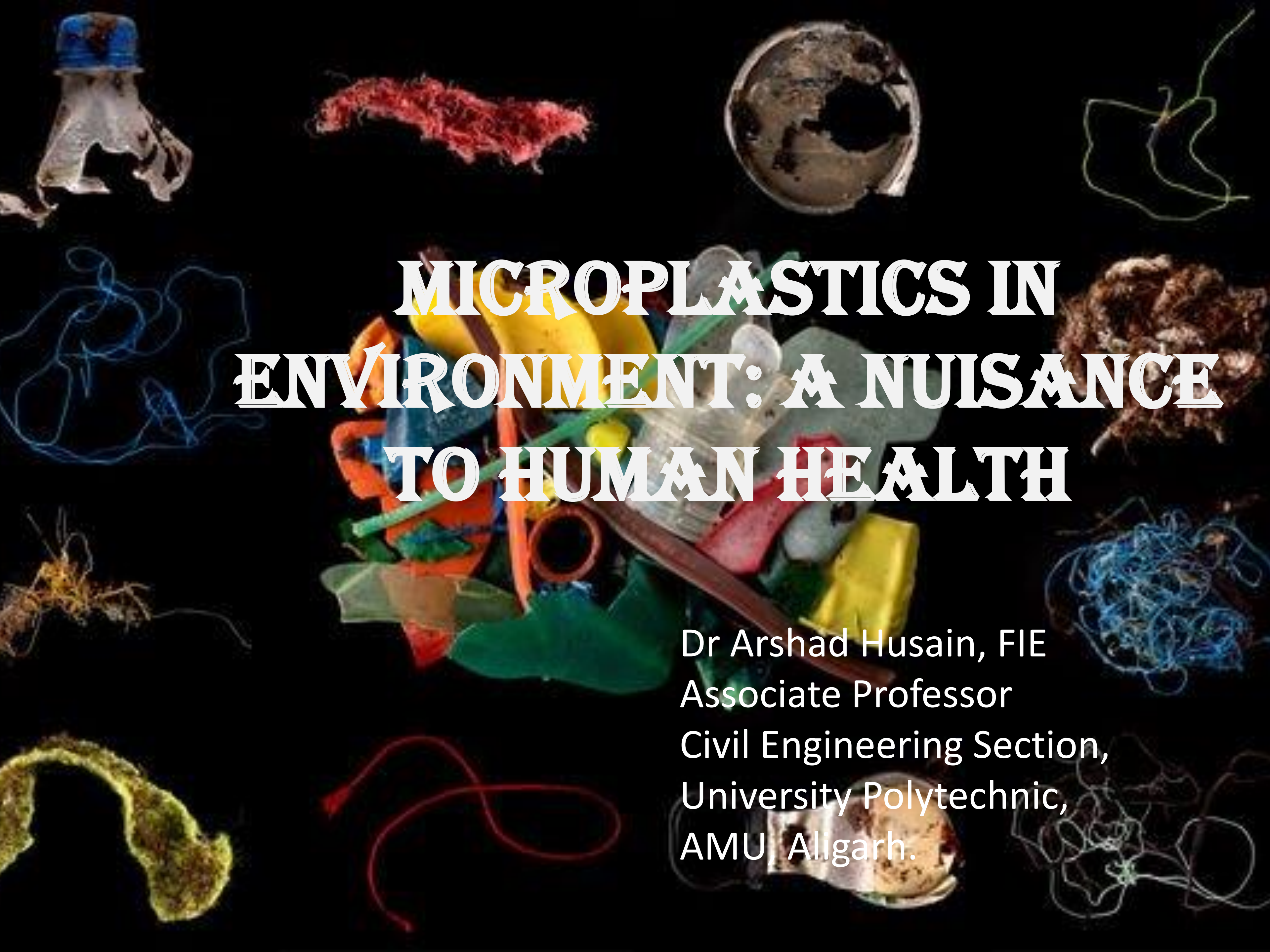


MICROPLASTICS IN ENVIRONMENT: A NUISANCE TO HUMAN HEALTH

Dr Arshad Husain, FIE
Associate Professor
Civil Engineering Section,
University Polytechnic,
AMU, Aligarh.

Introduction

- Plastics have much attention in the world due to their versatility, flexibility, low cost, durability, ease of manufacture and a hindrance to water
- Annually about 380 million tons of plastic are manufactured around the globe
- About 9% recycled and another 12% burned

(https://www.sciencenewsforstudents.org/article/help-for-a-world-drowning-in-microplastics)

- plastic fragments are ubiquitous on terrestrial environment, in freshwater and in marine
- Accumulation of plastic materials in the environment is known as plastic pollution which adversely affects nature

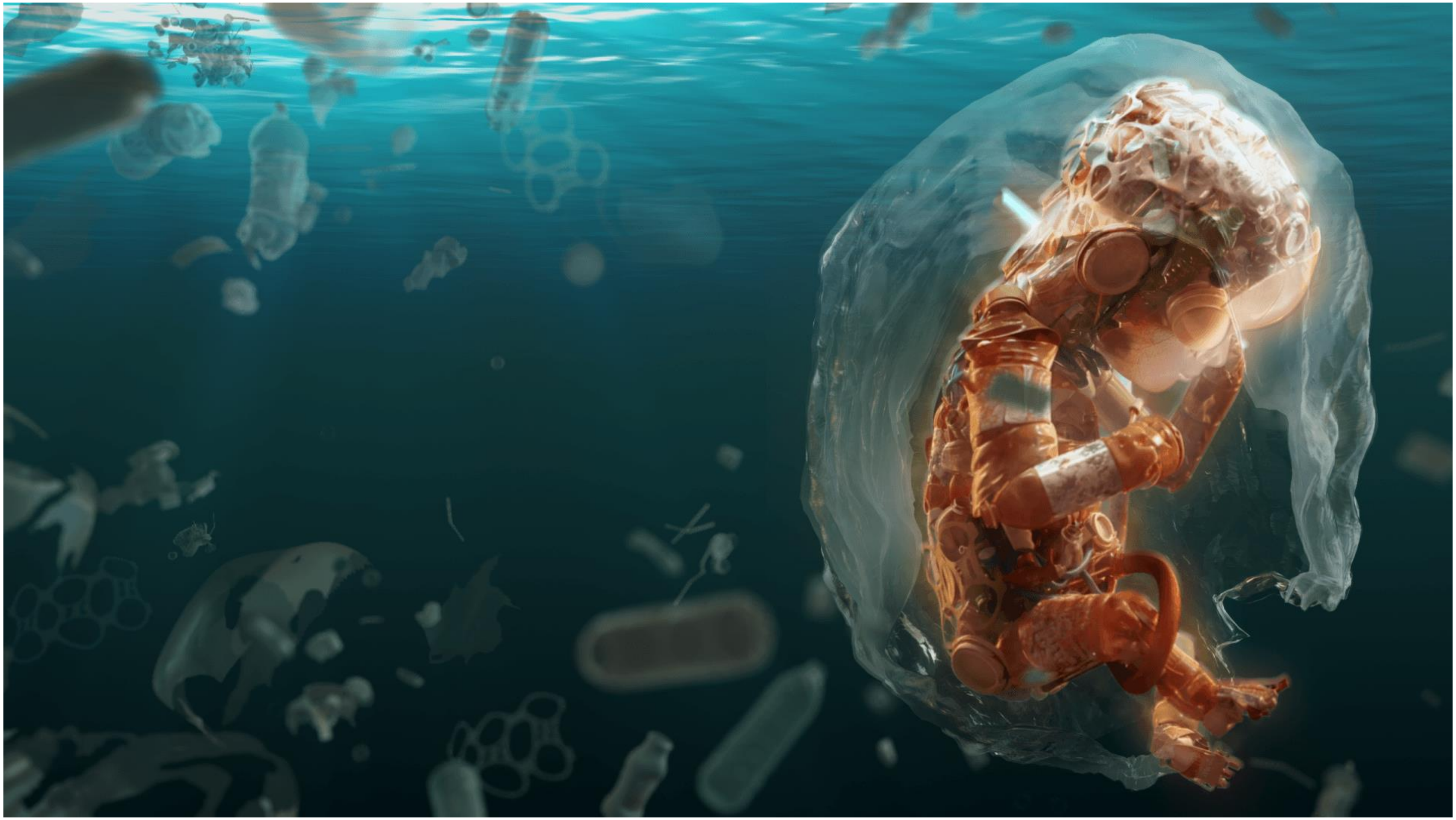
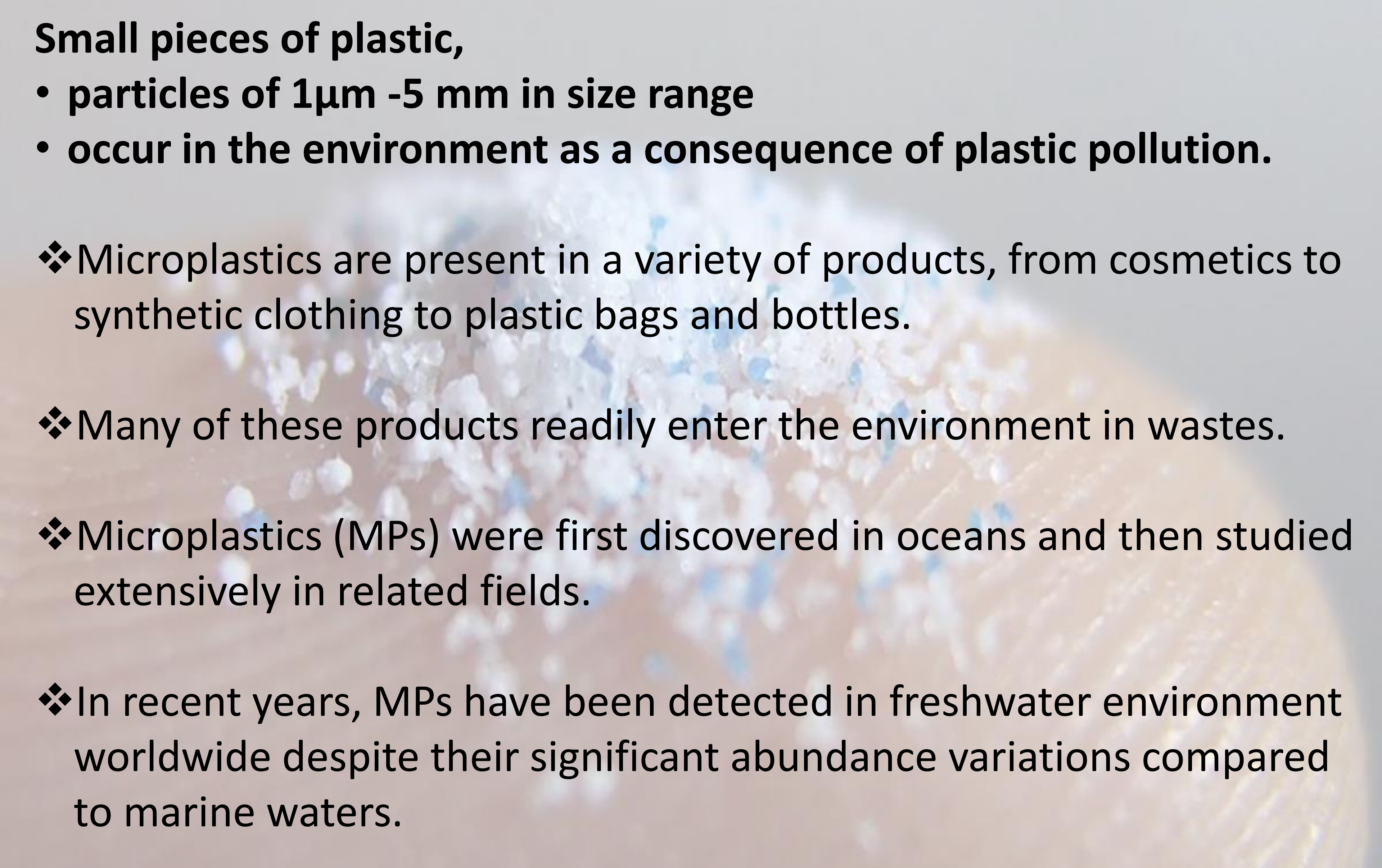


Fig 1 – Water pollution from MPs

[(https://solorganix.com/blogs/impact-the-world/microplastic-pollution-how-you-can-help-solve-the-problem)](https://solorganix.com/blogs/impact-the-world/microplastic-pollution-how-you-can-help-solve-the-problem)

What is Microplastics



Small pieces of plastic,

- **particles of 1µm -5 mm in size range**
- **occur in the environment as a consequence of plastic pollution.**

- Microplastics are present in a variety of products, from cosmetics to synthetic clothing to plastic bags and bottles.

- Many of these products readily enter the environment in wastes.

- Microplastics (MPs) were first discovered in oceans and then studied extensively in related fields.

- In recent years, MPs have been detected in freshwater environment worldwide despite their significant abundance variations compared to marine waters.

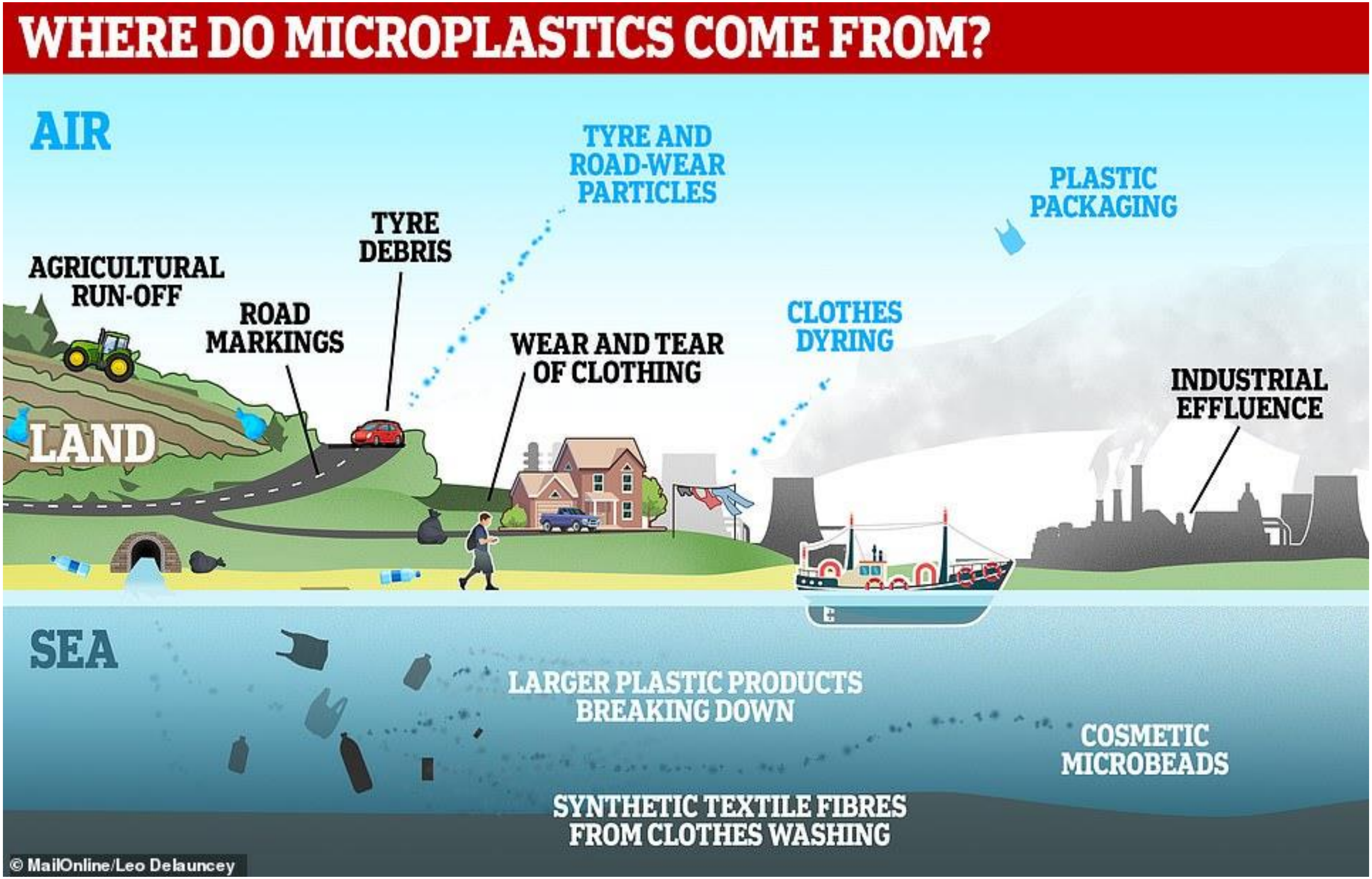


Fig 2 – Source of Microplastics

[(https://www.dailymail.co.uk/sciencetech/article-7379837/UN-drinking-water-report-calls-crackdown-microplastic-pollution.html)](https://www.dailymail.co.uk/sciencetech/article-7379837/UN-drinking-water-report-calls-crackdown-microplastic-pollution.html)

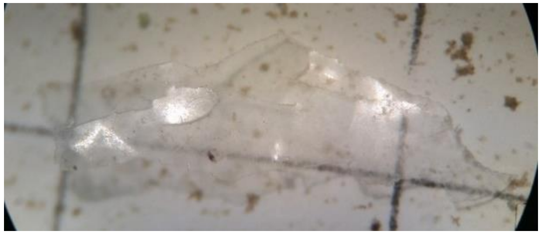
Types of Microplastics

PRIMARY MICROPLASTICS
Manufactured for direct use enter the environment in their « micro » size

SECONDARY MICROPLASTICS
Resulting from the breakdown of larger plastics in the environment

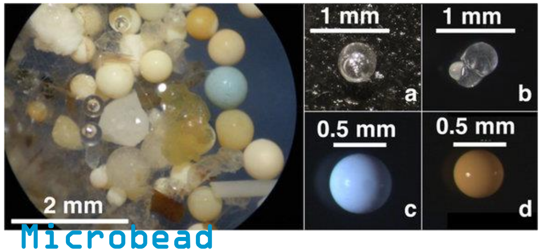

Fibres


Pellets


Films


Fragments


Foam



Microbeads

Fig 3 - Types of MPs

(http://www.waterkeeper.ca/blog/2016/11/15/zooming-in-on-the-five-types-of-microplastics)

What makes the microplastics?

PRIMARY MICROPLASTICS

MICROBEAD

Photo Credit: Minnesota Pollution Control Agency

Plastic beads in face washes, toothpaste, etc.

NURDLES

Photo Credit: Wikimedia Commons (https://commons.wikimedia.org/wiki/File:Nurdles_01_gentlemanrook.jpg)

Plastic beads made by plastic manufacturers

SECONDARY MICROPLASTICS

PLASTIC FILM

Photo Credit: Wikimedia Commons (https://tr.m.wikipedia.org/wiki/Dosya:Saran_Wrap_02.JPG)

Plastic wrap, zip locks & food packaging

RUBBER

Photo Credit: Wikimedia Commons (https://www.flickr.com/photos/71776010@N04/648402375)

Tires, shoes, gloves.

NYLON THREAD

Photo Credit: Wikimedia Commons (https://commons.wikimedia.org/wiki/File:1-DSC_0001_(18).jpg)

Fishing Nets & Clothes

POLYSTYRENE

Photo Credit: Wikimedia Commons (https://commons.wikimedia.org/wiki/File:Styrofoam_peanuts.JPG)

Foam food containers, cups and packaging

POLYPROPYLENE

Photo Credit: Wikimedia Commons (https://commons.wikimedia.org/wiki/File:Recyclables.JPG)

A LOT of stuff! Plastic bottles, food wrappers, phone cases...

Routes of human exposure to Microplastics

1. Ingestion:

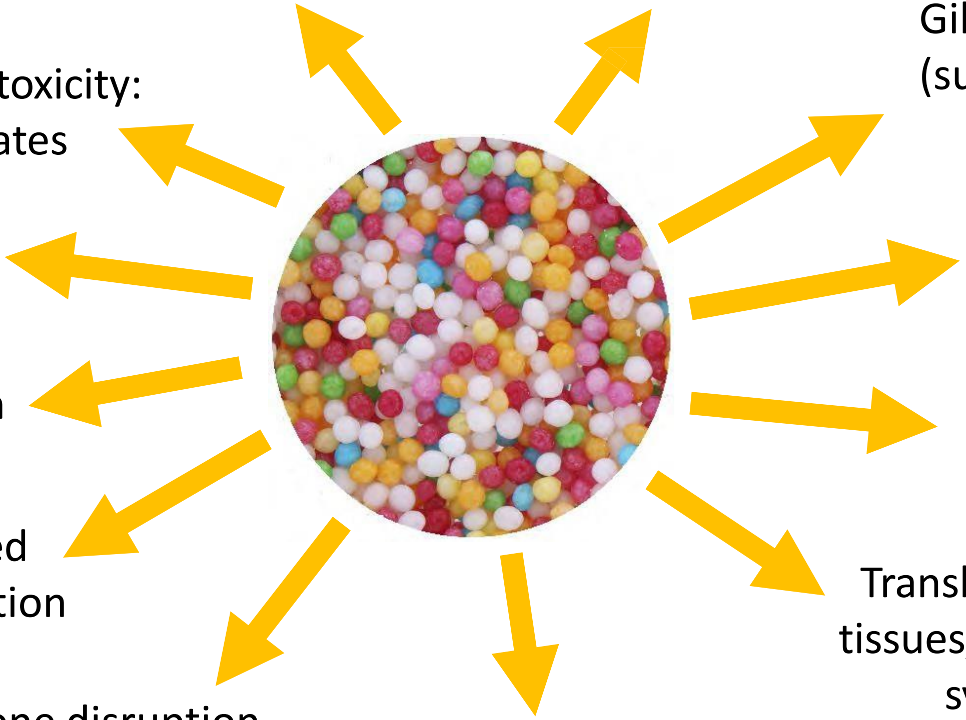
- Food

- Water

2. Inhalation: Air

3. Dermal Contact

Ecological effects of microplastics



Chemical toxicity: associated chemicals

Gut blockage

Gill blockage (suffocation)

Abrasion/ tissue damage

Bioaccumulation

Translocation to tissues/circulatory system

Increased stress

Hormone disruption

Impaired reproduction

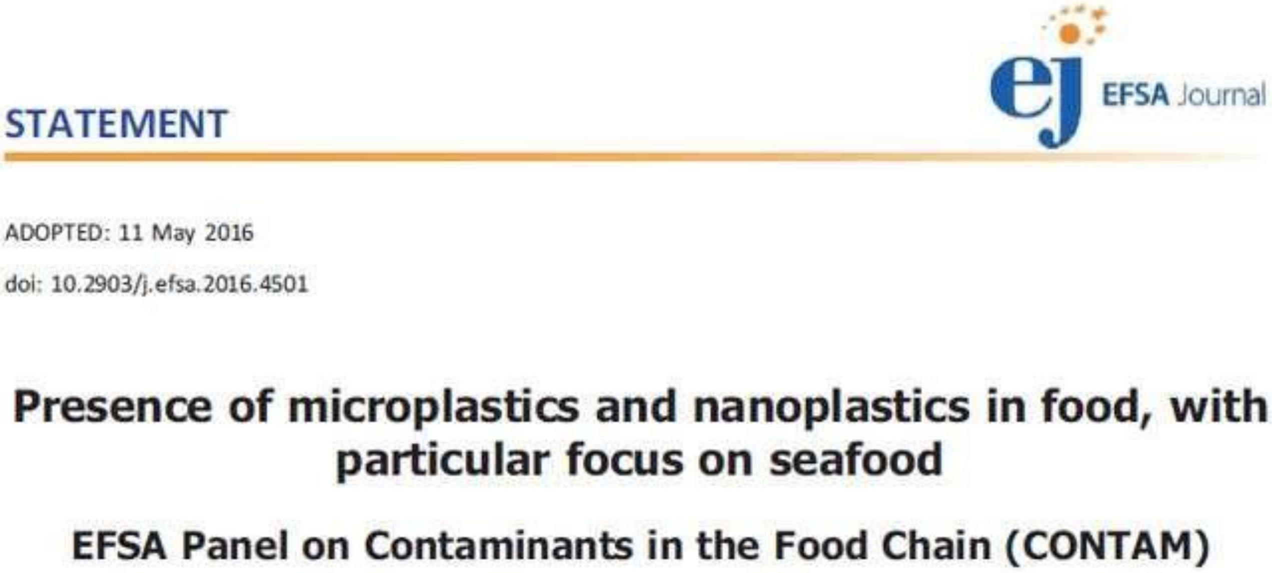
Inhibition of growth

Altered behaviour

Chemical toxicity: leachates

Wright et al. (2013) Environmental Pollution

Microplastics in food:



EFSA Journal

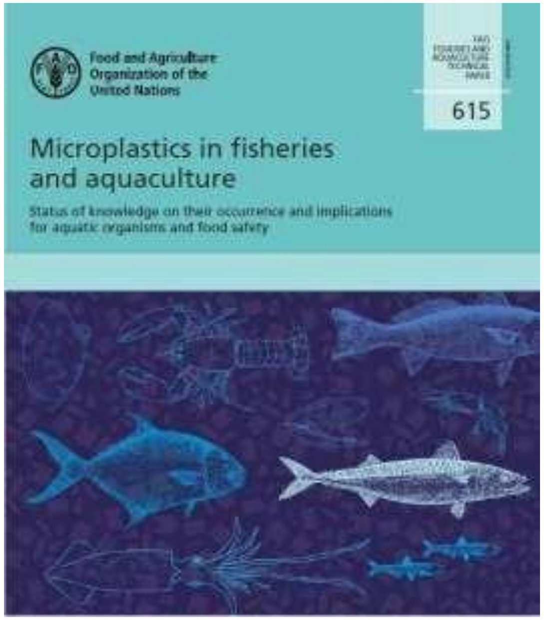
STATEMENT

ADOPTED: 11 May 2016

doi: 10.2903/j.efsa.2016.4501

Presence of microplastics and nanoplastics in food, with particular focus on seafood

EFSA Panel on Contaminants in the Food Chain (CONTAM)

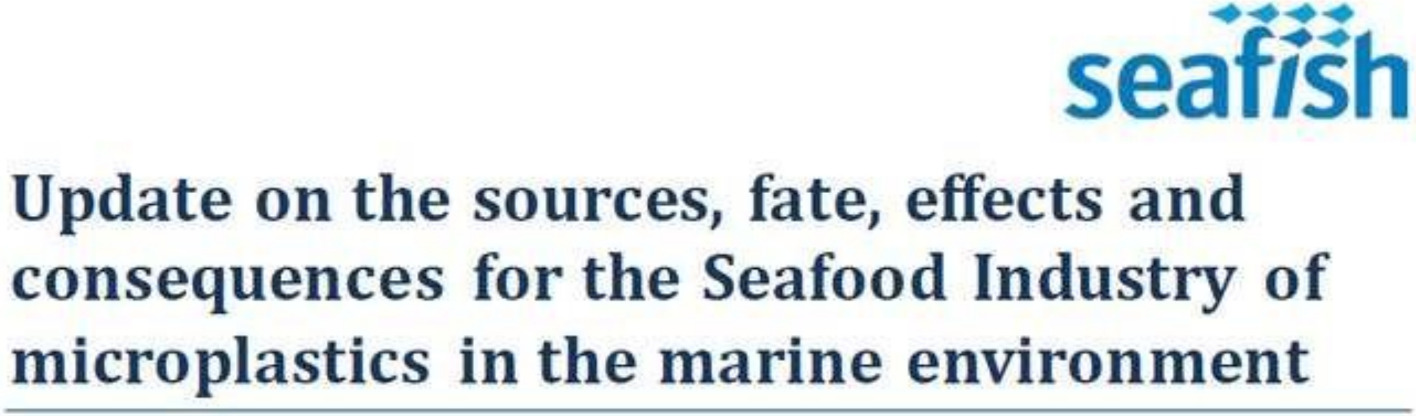


Food and Agriculture Organization of the United Nations

615

Microplastics in fisheries and aquaculture

Status of knowledge on their occurrence and implications for aquatic organisms and food safety



seafish

Update on the sources, fate, effects and consequences for the Seafood Industry of microplastics in the marine environment

Microplastics in food

Species	Location	Av No. MP / g soft tissue	Particle type	Reference
M. edulis	Germany (Aquaculture)	0.36 (±0.07)	Fragments, spheroids	Van Cauwenberghe & Janssen, 2014
C. Gigas	Germany (Aquaculture)	0.47 (±0.16)	Fragments, spheroids	Van Cauwenberghe & Janssen, 2014
9 different species	China (market bought)	4.0 (±2.1-10.5)	Fragments, fibres, pellets	Li et al., 2015
V. philippinarum	Canada (aquaculture)	1.13 (±0.66)	Fibres, film, fragments	Davidson & Dudas, 2016
M. edulis	Belgium	0.24	Fibres, fragments	De Witte et al., 2014
C. gigas	Belgium	0.35		
M. edulis	Scotland: Oban (wild)	1.05 (±0.66) – 4.44 (±3.03)	Fibre, film, fragments, beads	Courtene-Jones et al., 2016
Mytilus spp.	Industrial Estuary Scotland	0.74 (±0.125)	Fibres	Catarino et al., 2018
Mytilus spp.	Scotland: Various (wild)	3.0 (± 0.9)	Fibres	Catarino et al., 2018

Food type	Location	Av No MP/KG	Av No MP/g	Particle type	Reference
Honey*	Germany	166 ± 147	0.166 ± 147	Fibres, Fragments	Liebezeit et al., 2013.
Sugar*	Germany	249 ± 130	0.249 ± 130	Fibres, Fragments	
Sea salt	China	550–681	0.55-0.681	Fragments, fibres, pellets	Yang et al., 2015
Lake salt	China	43–364	0.043-0.364	Fragments, fibres, pellets	
Rock/well salt	China	7– 204	0.07-0.204	Fragments, fibres, pellets	
Salt	International	1-10	0.001-0.01	Fragments, filaments, films	Karami et al., 2017

ELSEVIER

Estuarine, Coastal and Shelf Science

Volume 219, 5 April 2019, Pages 161-168

Microplastic pollution in commercial salt for human consumption: A review

Diogo Peixoto[a], Carlos Pinheiro[a], João Amorim[a], Luís Oliva-Teles[a, b], Lúcia Guilhermino[a, c], Maria Natividade Vieira[a, b]

Microplastics in Water: Ingestion

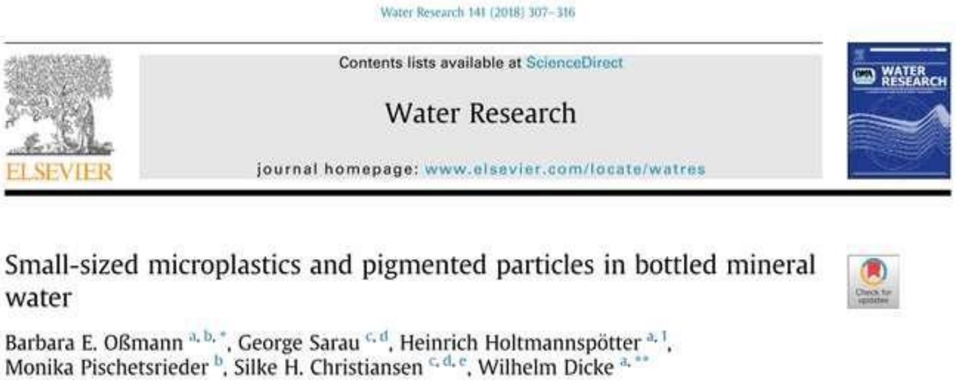

PLOS | ONE

RESEARCH ARTICLE

Anthropogenic contamination of tap water, beer, and sea salt

Mary Kosuth[1☯]*, Sherri A. Mason[2☯], Elizabeth V. Wattenberg[1☯]

1 University of Minnesota, School of Public Health, Division of Environmental Health Sciences, Minneapolis, Minnesota, United States of America, 2 State University of New York at Fredonia, Department of Chemistry and Biochemistry, Fredonia, New York, United States of America


Water Research 141 (2018) 307–316

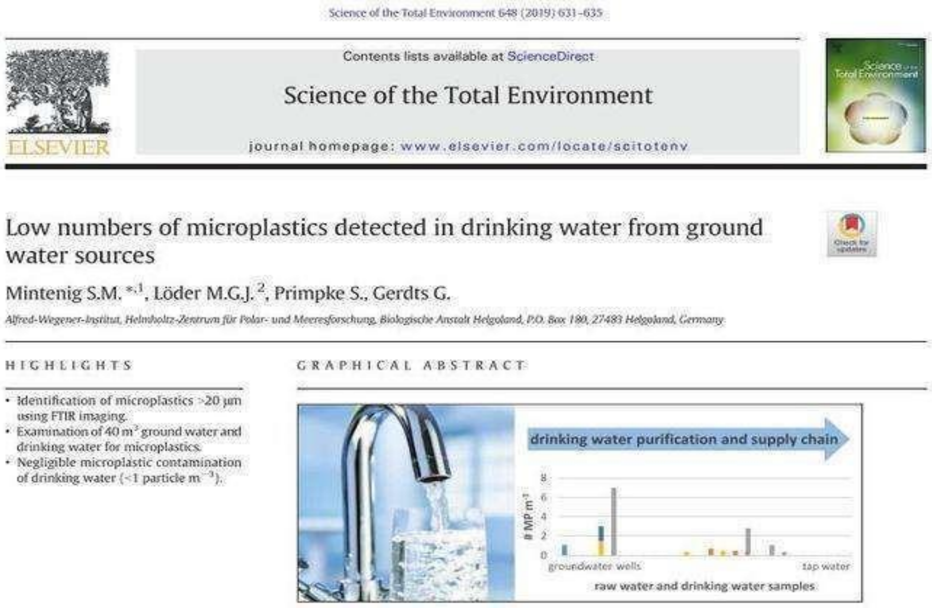
Contents lists available at ScienceDirect

Water Research

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

Small-sized microplastics and pigmented particles in bottled mineral water

Barbara E. Oßmann[a, b, *], George Sarau[c, d], Heinrich Holtmannspötter[a, 1], Monika Pischetsrieder[b], Silke H. Christiansen[c, d, e], Wilhelm Dicke[a, **]


Science of the Total Environment 648 (2019) 631–635

Contents lists available at ScienceDirect

Science of the Total Environment

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

Low numbers of microplastics detected in drinking water from ground water sources

Mintenig S.M. [*,1], Löder M.G.J. [2], Primpke S., Gerdts G.

Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung, Biologische Anstalt Helgoland, P.O. Box 180, 27483 Helgoland, Germany

HIGHLIGHTS

- Identification of microplastics >20 µm using FTIR imaging.
- Examination of 40 m^3 ground water and drinking water for microplastics.
- Negligible microplastic contamination of drinking water (<1 particle m^{-3}).

GRAPHICAL ABSTRACT


Water Research 129 (2018) 154–162

Contents lists available at ScienceDirect

Water Research

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

Analysis of microplastics in water by micro-Raman spectroscopy: Release of plastic particles from different packaging into mineral water

Darena Schymanski[a, b], Christophe Goldbeck[a], Hans-Ulrich Humpf[b], Peter Fürst[a, *]

Microplastics in Water: Ingestion


Current Opinion in Environmental Science & Health
Volume 7, February 2019, Pages 69-75

Microplastics in drinking water: A review and assessment

Dafne Eerkes-Medrano [1], Heather A. Leslie [2], Brian Quinn [3]

Reference	Type of DW measured (number of samples)	Volumes collected per sample	Min & max values; mean concentration	Size range of particles	Type of particles	Composition of particles
*Kosuth et al. 2018	Tap water (n=156), Bottled water (n=3)	500ml	0 to 60.9 particles/L; 5.45 particles/L	0.10-5.00mm, (Av.0.96mm)	Fibres, fragments, films	NA
Mintenig et al. 2018	Raw water at DWTP inlet (n=6), DW at DWTP outlet (n=5), DW at household water meter (n=5) and water tap (n=5), well ground water (n=3)	300-1000L raw water, 1200-2500L DW	0 to 7 particles/m3; 0.7 particles/m3 (14 of the 24 samples had no MP detected)	50-150µm	fragments, fibers were suspected as contamination	PEST, PVC, PA, epoxy, and PE.
Oßmann et al. 2018	Mineral water packaged in PET reusable bottles (n=12), single use PET bottles (n=10), reusable glass bottles (n=9), single use glass bottle (n=1)	250ml of initial sample volume	0 to 16634 particles/L; mean 3633.26±3860.96 particles/L.	1 µm to >10µm	NA	PET, PET, PE, PP
Schymanski et al. 2018	Returnable plastic bottles (n=15), single-use plastic bottles (n=11), glass bottles (n=9)	700-1500ml	2 to 241 particles/L; particles per L in single-use plastic bottles (14±14), returnable plastic bottles (118±88), glass bottles (50±52)	5 µm to >100 µm;	fragments	PET, PEST, PE, PP, PA, others

* Kosuth et al. 2018 reported “anthropogenic particles” as FTIR was not applied to identify particle composition

Researchers have found plastic pollution across the world's oceans.

WHAT WE KNOW

1. Plastic accumulates in ocean gyres
2. Marine debris can harm the ocean life
3. **A lot of ocean debris is *microplastics***

Microplastics are pieces of plastic that are smaller than 5 mm in diameter. They can be *primary microplastics* or *secondary microplastics.*

Primary microplastics are microplastics that have always been smaller than 5 mm (e.g. a bead). Secondary microplastics are microplastics that broke down from a large piece of plastic to become smaller than 5 mm.

Photo Credit: Meredith Evans Seeley

Microplastics in air: Inhalation

Environmental Pollution 221 (2017) 453–458

Contents lists available at ScienceDirect

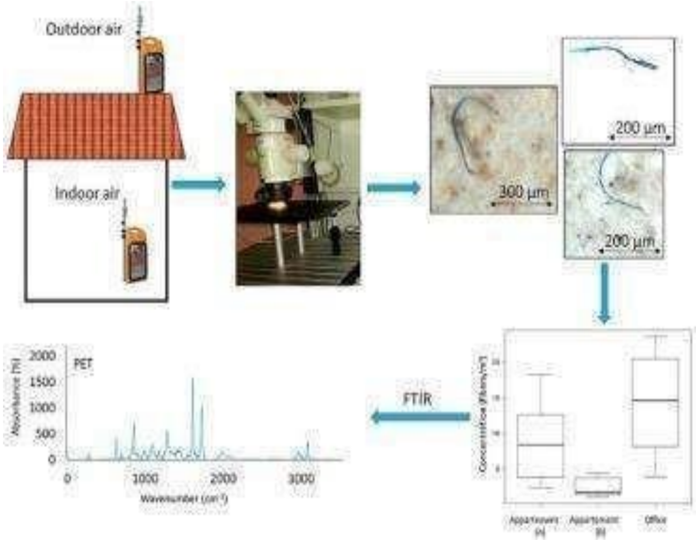
Environmental Pollution

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

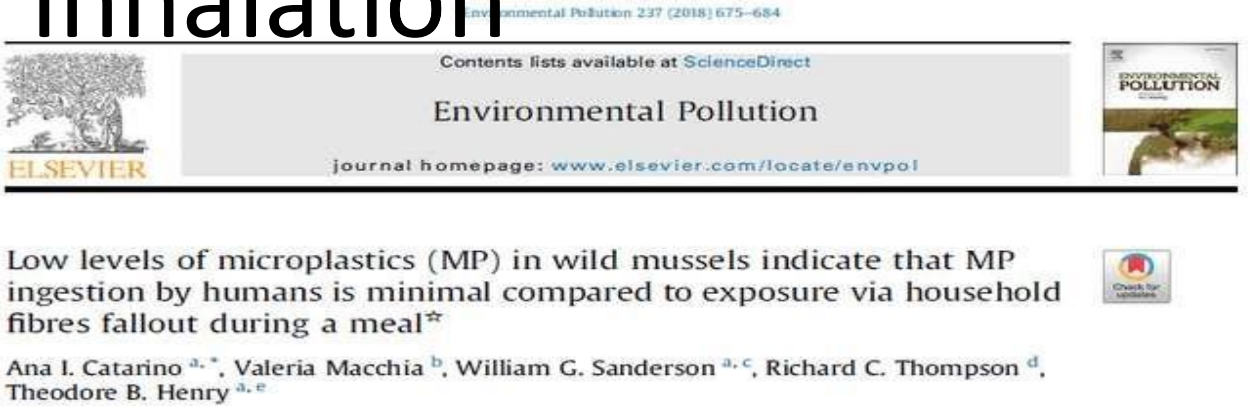
A first overview of textile fibers, including microplastics, in indoor and outdoor environments[☆]

Rachid Dris [a, *], Johnny Gasperi [a, **], Cécile Mirande [a], Corinne Mandin [b], Mohamed Guerrouache [c], Valérie Langlois [c], Bruno Tassin [a]

- Indoor concentrations between 1.0 and 60.0 fibers/m^3
- 33% fibers contain petrochemicals with polypropylene
  being predominant
- There is currently no available data or information which provides evidence of the potential human health effects of ingested or inhaled microplastics.



Microplastics in air: Inhalation



Environmental Pollution 237 (2018) 675–684

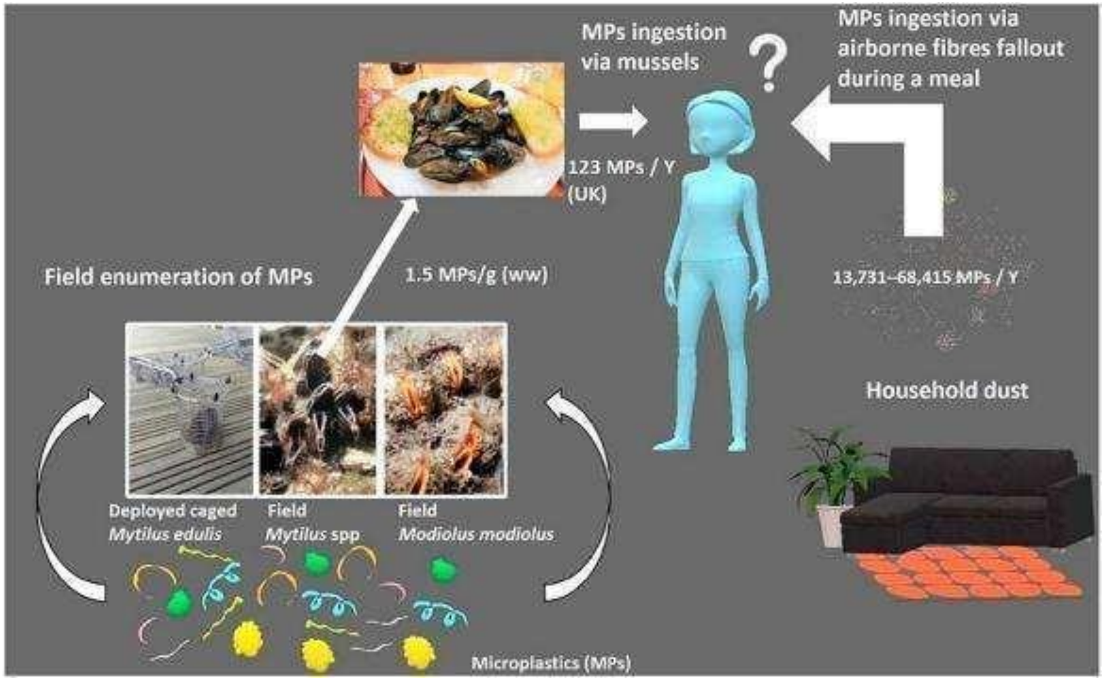
Contents lists available at ScienceDirect

Environmental Pollution

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

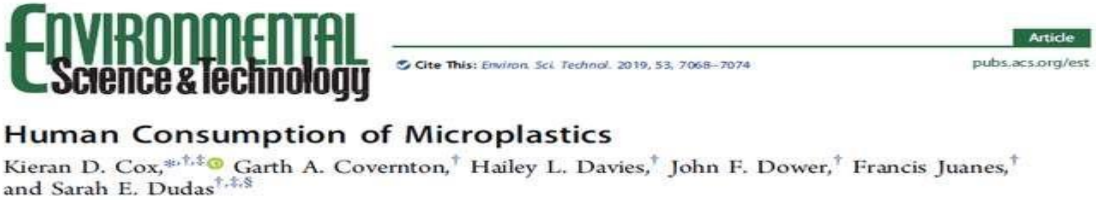
Low levels of microplastics (MP) in wild mussels indicate that MP ingestion by humans is minimal compared to exposure via household fibres fallout during a meal☆

Ana I. Catarino [a, *], Valeria Macchia [b], William G. Sanderson [a, c], Richard C. Thompson [d], Theodore B. Henry [a, e]



‘Concerns of human to MPs via shellfish ingestion need to be **placed into context**, since their **potential for ingestion is minimal when compared to exposure to MPs via household dust fallout**’.

Microplastic Consumption



Cite This: Environ. Sci. Technol. 2019, 53, 7068−7074

Human Consumption of Microplastics

Kieran D. Cox,[*,†,‡] Garth A. Coverton,[†] Hailey L. Davies,[†] John F. Dower,[†] Francis Juanes,[†] and Sarah E. Dudas[†,‡,§]

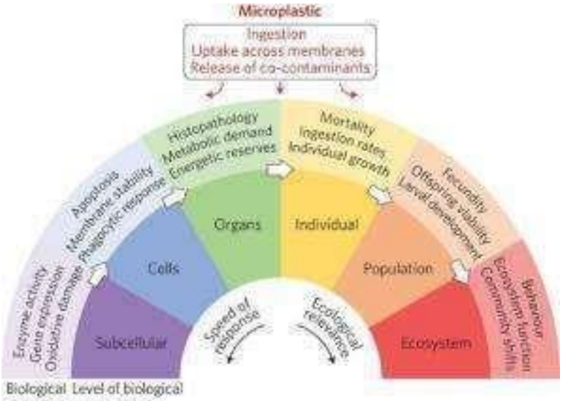
- Based on caloric intake, estimate that annual MP consumption ~**39,000 to 52,000** particles depending on age and sex, increasing to **74,000 and 121,000** when inhalation is considered.
- Recommended water intake through only bottled sources ingesting an additional 90,000 MPs annually, compared to 4,000 MPs for tap water only.

ORIGINAL RESEARCH | 1 OCTOBER 2019

Detection of Various Microplastics in Human Stool: A Prospective Case Series

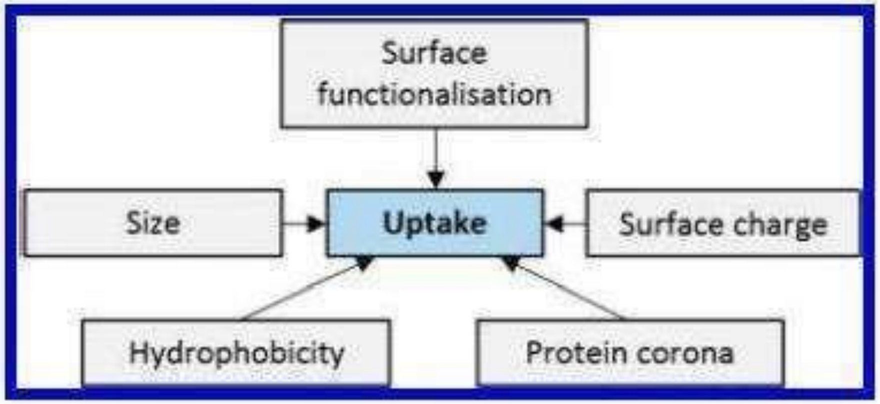
Philipp Schwabl, MD; Sebastian Köppel, Dipl-Ing(FH); Philipp Königshofer, DVM; Theresa Bucsics, MD; Michael Trauner, MD; Thomas Reiberger, MD; Bettina Liebmann, PhD

Potential impact of Microplastics on humans



Galloway et al., (2017). Nature Ecology & Evolution 1, Article number: 0116

- How to define impact?
- At what level do we assess impact?
  1. Particle toxicity hazard
  2. Exposure to micromolecules sorbed to MP
- Potential impacts:
- MP physical & chemical characteristics will influence toxicological risk



Wright SL, Kelly FJ: Plastic and human health: a micro issue? Environ Sci Technol 2017, 51(12):6634-47.

Potential impact: Particle toxicity hazard

Environ. Sci. Technol., **2017**, *51* (12), pp 6634–6647

Environmental Science & Technology

Critical Review

pubs.acs.org/est

Plastic and Human Health: A Micro Issue?

Stephanie L. Wright*‡ and Frank J. Kelly‡

- Could lead to a suite of biological responses; inflammation, genotoxicity, oxidative stress, apoptosis & necrosis.
- Potentially leading to tissue damage, fibrosis and carcinogenesis.
- Evidence is provided by wear debris from plastic prosthetic implants.
- PE particles (0.5−50 µm) provoke a non-immunological foreign body response
- PE particles transportation via the perivascular lymph spaces occurs

Potential impact: Particle toxicity hazard

Science of the Total Environment 684 (2019) 657–669

Contents lists available at ScienceDirect

Science of the Total Environment

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

Short Communication

An assessment of the toxicity of polypropylene microplastics in human derived cells

Jangsun Hwang [a,b], Daheui Choi [a], Seora Han [a], Jonghoon Choi [b,*], Jinkee Hong [a,*]

- PP particles showed low cytotoxicity effect in size and concentration manner
- However, a high concentration, small sized, DMSO method of PP particles stimulated the immune system and enhanced potential hypersensitivity to PP particles via an increase in the levels of cytokines and histamines in PBMCs, Raw 264.7 and HMC-1 cells.

Potential impact: Particle toxicity hazard

Environmental Pollution 234 (2018) 115–126

Contents lists available at ScienceDirect

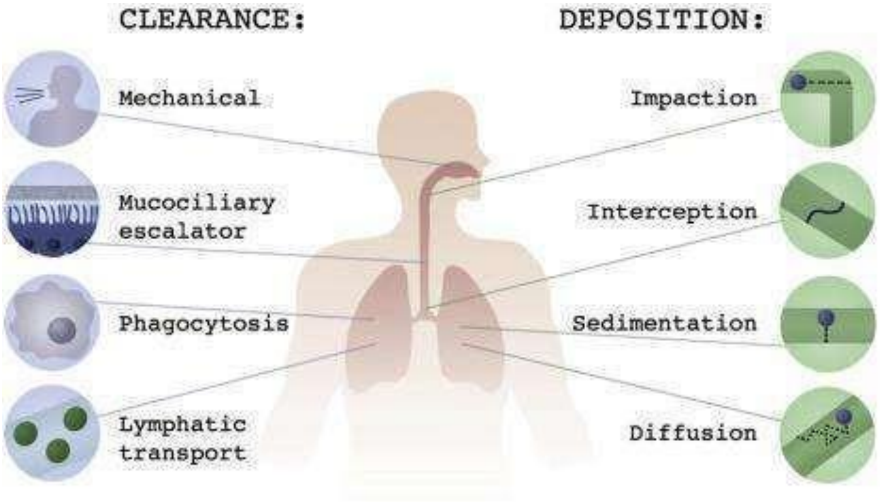
Environmental Pollution

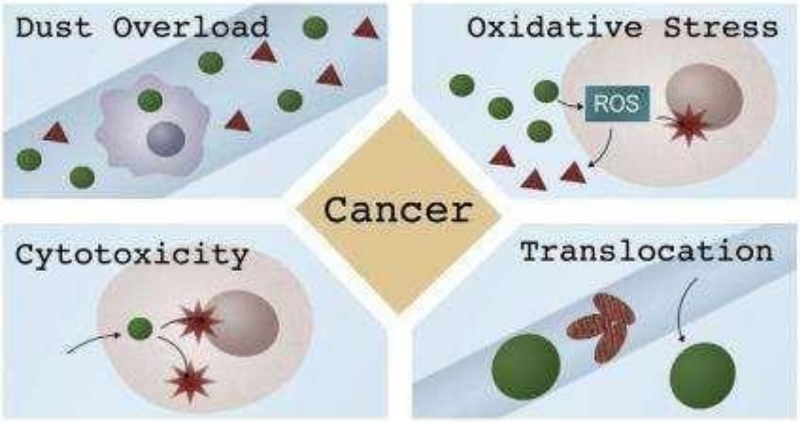
journal homepage: www.elsevier.com/locate/envpol

Airborne microplastics: Consequences to human health?*

Joana Correia Prata

University Fernando Pessoa, Fernando Pessoa Energy, Environment and Health Research Unit (FP ENAS), Praça 9 de Abril, 349, Porto, Portugal





Potential impact: Particle toxicity

ELSEVIER

Science of The Total Environment

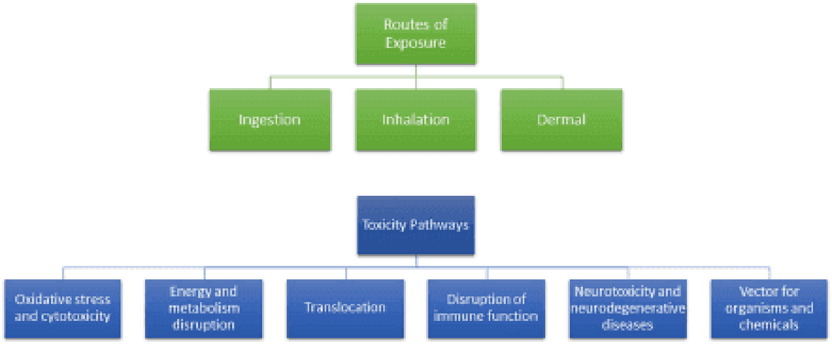
Available online 4 October 2019, 134455

In Press, Journal Pre-proof

Review

Environmental exposure to microplastics: an overview on possible human health effects

Joana Correia Prata [a], João P. da Costa [a], Isabel Lopes [b], Armando C. Duarte [a], Teresa Rocha-Santos [a]

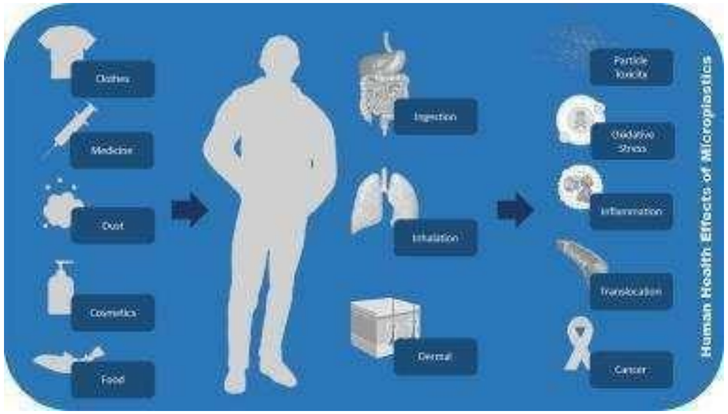


Routes of Exposure

- Ingestion
- Inhalation
- Dermal

Toxicity Pathways

- Oxidative stress and cytotoxicity
- Energy and metabolism disruption
- Translocation
- Disruption of immune function
- Neurotoxicity and neurodegenerative diseases
- Vector for organisms and chemicals



- Under conditions of high concentration or high individual susceptibility, microplastics **may** cause inflammatory lesions.
- However, **knowledge** on the effects of environmental exposure to microplastics on human health **is limited**, leading to high uncertainties that **should not be translated in alarmism** even when applying the precautionary principle.

Potential impact: Particle toxicity hazard

Science of the Total Environment 667 (2019) 94–100

Contents lists available at ScienceDirect

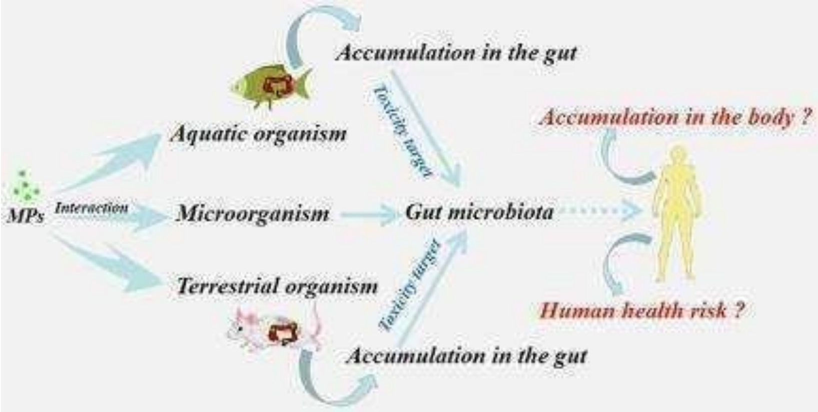
Science of the Total Environment

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

Review

Interaction between microplastics and microorganism as well as gut microbiota: A consideration on environmental animal and human health

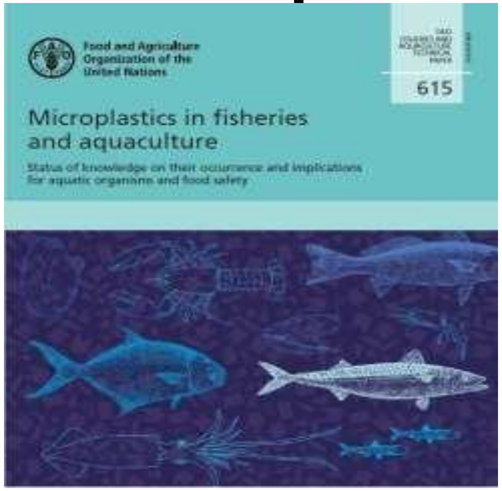
Liang Lu, Ting Luo, Yao Zhao, Chunhui Cai, Zhengwei Fu, Yuanxiang Jin *



- Microplastics **could** interact with microorganisms as well as gut microbiota.
- Microplastics **may** affect host health through effects on gut microbiota.
- Effects of microplastics on gut microbiota **need more attention**.

Exposure of micromolecules via microplastics

Exposure assessment using bivalves



Food and Agriculture Organization of the United Nations

615

Microplastics in fisheries and aquaculture

Status of knowledge on their occurrence and implications for aquatic organisms and food safety

Compound	Highest concentration in microplastics (see section 5.6) (ng/g)	Calculated intake from microplastics (pg/kg bw/day)	Total intake from the diet (pg/kg bw/day)	Ratio intake microplastic/total dietary intake (%)
Contaminants				
Non-dioxin like PCBs	2 970	0.3		
EFSA, 2012			4 300[a]	0.007
JECFA, 2016			1 000[a]	0.03
PAHs	44 800	4.5		
EFSA, 2008			28 800[b]	0.02
JECFA, 2006			4 000[c]	0.1
DDT	2 100	0.2		
EFSA, 2006			5 000[d]	0.004
JECFA, 1960			100 000 000[j]	0.0000002
Additives/monomers				
Bisphenol A	200	0.02		
EFSA, 2015a			130 000[e]	0.00002
FAO/WHO, 2011			400 000[f]	0.000005
PBDEs	50	0.005		
EFSA, 2011			700[g]	0.0007
JECFA, 2006			185[h]	0.003
NP	2 500	0.3	NA[i]	
OP	50	0.005	NA[i]	

Note: EFSA (European Food Safety Authority), JECFA (Joint (FAO/WHO) Expert Committee on Food Additives, FAO (Food and Agriculture Organization of the United Nations), WHO (World Health Organisation), PCBs (Polychlorinated biphenyls), PAHs (Polycyclic aromatic hydrocarbons), DDT (Dichlorodiphenyltrichloroethane), PBDEs (Polybrominated diphenyl ethers), NP (Nonylphenol), OP (Octylphenol).

Exposure of micromolecules

Current Opinion in Environmental Science & Health
Available online 11 December 2018
In Press, Corrected Proof

Microplastics in drinking water: A review and assessment

Dafne Eerkes-Medrano [1], Heather A. Leslie [2], Brian Quinn [3]

Compound	Highest concentration in MP (ng/g)	Calculated intake from treated water (pg/kg bw/day)	Calculated intake from tap water (pg/kg bw/day)	Calculated intake from bottled water (pg/kg bw/day)	Total intake from diet (pg/kg bw/day)	Ratio intake treated water MP/total dietary intake (%)	Ratio intake tap water MP/total dietary intake (%)	Ratio intake bottle water MP/total dietary intake (%)
Contaminants								
Non-dioxin like PCBs	2970	0.0026136	12.2364	0.0594				
EFSA, 2012					4300	6.08E-05	**0.28**	**1.38E-03**
JECFA, 2016					1000	2.61E-04	**1.22**	**5.94E-03**
PAHs	44800	0.039424	184.576	0.896				
ESFA, 2008					28800	1.37E-04	**0.64**	**3.11E-03**
JECFA, 2006					4000	9.86E-04	**4.61**	**0.02**
DDT	2100	0.001848	8.652	0.042				
EFSA, 2006					5000	3.70E-05	**0.17**	**8.40E-04**
JECFA, 1960					100000000	1.85E-09	**8.65E-06**	**4.20E-08**
Additives								
Bisphenol A	200	0.000176	0.824	0.004				
EFSA, 2015a					130000	1.35E-07	**6.34E-04**	**3.08E-06**
FAO/WHO, 2011					400000	4.40E-08	**2.06E-04**	**1.00E-06**
PBDEs	50	0.000044	0.206	0.001				
EFSA, 2011					700	6.29E-06	**0.03**	**1.43E-04**
JECFA, 2006					185	2.38E-05	**0.11**	**5.41E-04**

MP concentrations in DW would contribute a small fraction (8.6×10^{-6} to 4.6 % for tap water and 4.2×10^{-8} to 0.02 % for bottled water respectively) of the total dietary intake of environmental contaminants and additives.

Microplastic impact on humans

Science of the Total Environment 626 (2018) 720–726

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Science of the Total Environment

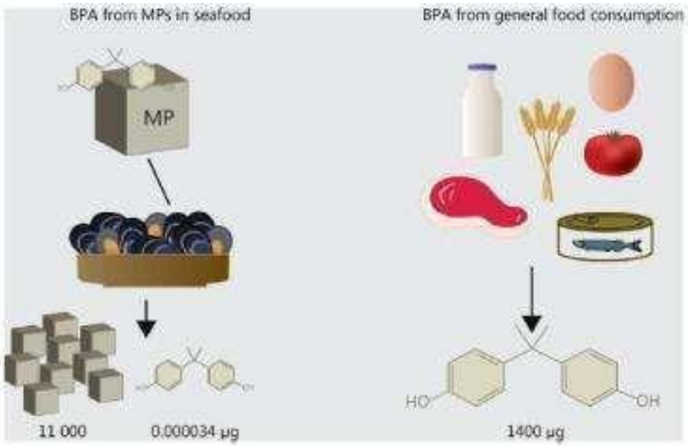
journal homepage: www.elsevier.com/locate/scitotenv

A critical perspective on early communications concerning human health aspects of microplastics

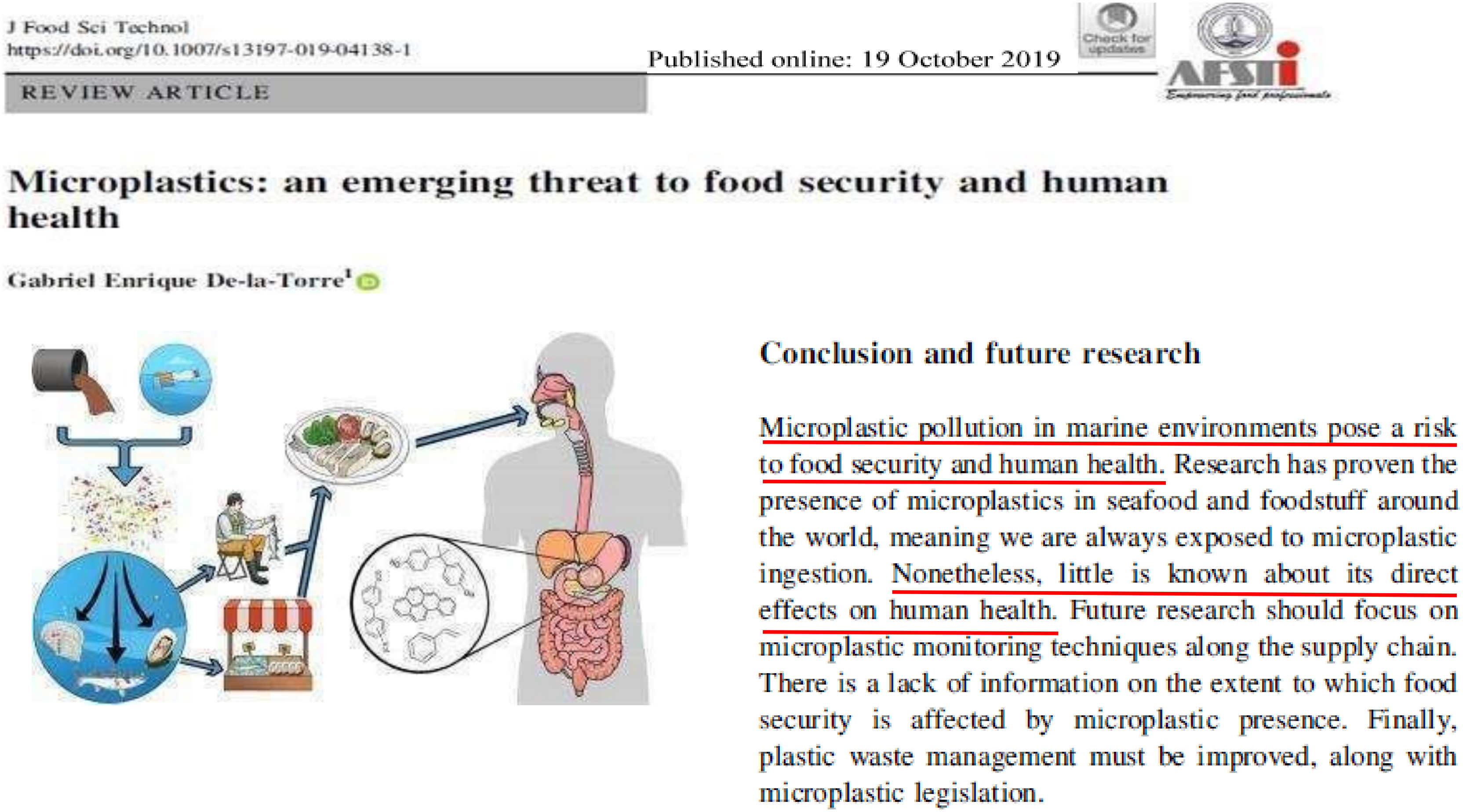
Sinja Rist [a], Bethanie Carney Almroth [b], Nanna B. Hartmann [a], Therese M. Karlsson [c,*]

[a] Technical University of Denmark, Department of Environmental Engineering, Bygningstorvet, Building 115, 2800 Kgs. Lyngby, Denmark
[b] University of Gothenburg, Department of Biological and Environmental Sciences, Medicinaregatan 18A, 41390 Göteborg, Sweden
[c] University of Gothenburg, Department of Marine Sciences, Kristineberg Marine Research Station, 45178 Fiskebäckskil, Sweden

- There is a **big discrepancy between the magnitude of this debate and actual scientific findings**, which have merely shown the presence of microplastics in certain products.
- Microplastics from food products and beverages likely only constitute a **minor exposure pathway** for plastic particles and associated chemicals to humans.
- But as this is **rarely put into perspective**, the recent debate has created a **skewed picture of human plastic exposure.**



Microplastic impact on humans



J Food Sci Technol
https://doi.org/10.1007/s13197-019-04138-1

REVIEW ARTICLE

Microplastics: an emerging threat to food security and human health

Gabriel Enrique De-la-Torre[1]

Conclusion and future research

Microplastic pollution in marine environments pose a risk to food security and human health. Research has proven the presence of microplastics in seafood and foodstuff around the world, meaning we are always exposed to microplastic ingestion. Nonetheless, little is known about its direct effects on human health. Future research should focus on microplastic monitoring techniques along the supply chain. There is a lack of information on the extent to which food security is affected by microplastic presence. Finally, plastic waste management must be improved, along with microplastic legislation.

Microplastic and human health: Risk

Risk Assessment

- Risk Assessment Home
- About Risk Assessment
- Risk Recent Additions

Conducting a Human Health Risk Assessment

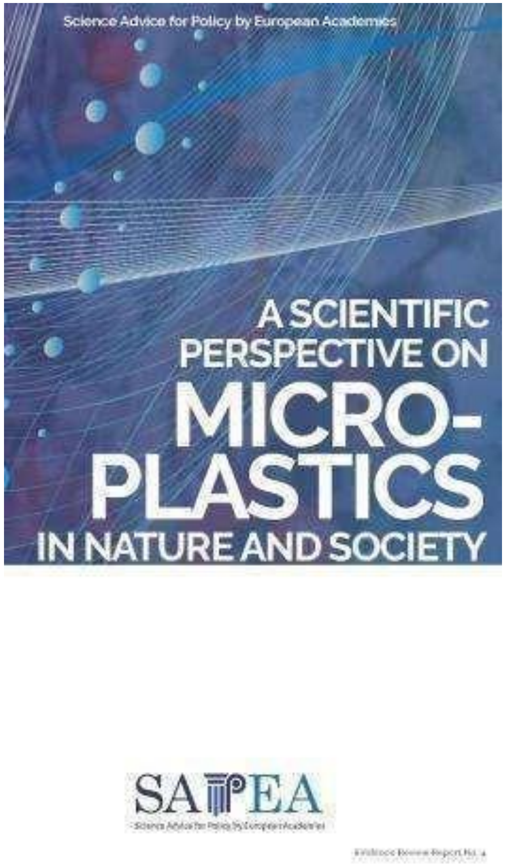
The 4 Step Risk Assessment Process

Hazard Identification
What health problems are caused by the pollutant?

Dose-Response Assessment
What are the health problems at different exposures?

Exposure Assessment
How much of the pollutant are people exposed to during a specific time period? How many people are exposed?

Risk Characterization
What is the extra risk of health problems in the exposed population?



Science Advice for Policy by European Academies

A SCIENTIFIC PERSPECTIVE ON MICROPLASTICS IN NATURE AND SOCIETY

<u>Data gaps</u> in both exposure and hazard preclude an adequate risk characterization of MP to humans, via DW or any other route.

Laboratory Methods for the Analysis of MPs

1. Sample Collection

- River sites are selected as sampling sites that are equally distributed in urbanized city area
- Both surface water and sediment samples are collected
- Surface water samples → metal cylinder by trawling → filtered with a glass fiber filter (60 µm)

↓

collected solid sample are rinsed Milli-Q water

- Three duplicate samples are collected at each sampling site
- Sediment samples → stainless shovel → covered with aluminum foil
- Three duplicate samples will be collected at each sampling site. All sediment samples are stored at the refrigerator for analysis.

Removal of Microplastics in water

- Coagulation
- Flocculation
- Granular Activated Carbon (GAC) Filtration

Fig 4 (a) - Water treatment plant

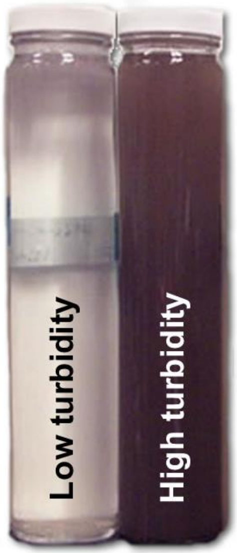


Fig 4 (b) - Turbidity of water

https://www.aquatechtrade.com/news/wastewater/microplastics-drinking-water-analysis/

Coagulation

Colloids

- Particle diameter < 1 µm
- Due to their physical size, they cannot be removed from suspension by ordinary physical separation processes
- Very slow settling characteristics of colloids (Brownian motion hinders their settlement under the effect of gravity) Contribute large parts of pollution and specific cause of turbidity (high ration of surface area to mass) because of very small size
- Surface properties (Z potential and electrical charges) becomes more important than sedimentation under gravity.

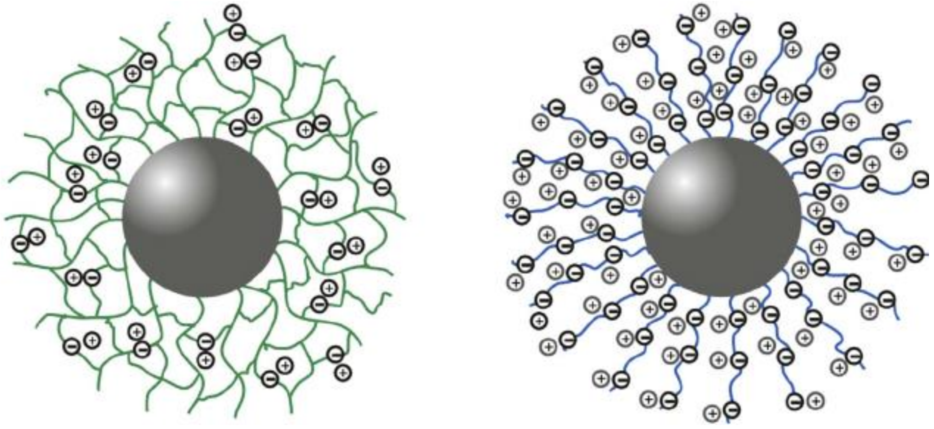


Fig 5 – Schematic diagram of a colloidal particle

Welsch, N., Lu, Y., Dzubiella, J. and Ballauff, M., 2013. Adsorption of proteins to functional polymeric nanoparticles. Polymer, 54(12), pp.2835-2849.

Coagulation cntd.

Addition of a chemical to water with the objective of destabilizing particles so they aggregate or forming a precipitate that will sweep particle from solution or absorb dissolved constituents.

(Howe, K.J., Hand, D.W., Crittenden, J.C., Trussell, R.R. and Tchobanoglous, G., 2012. Principles of water treatment. John Wiley & Sons.)

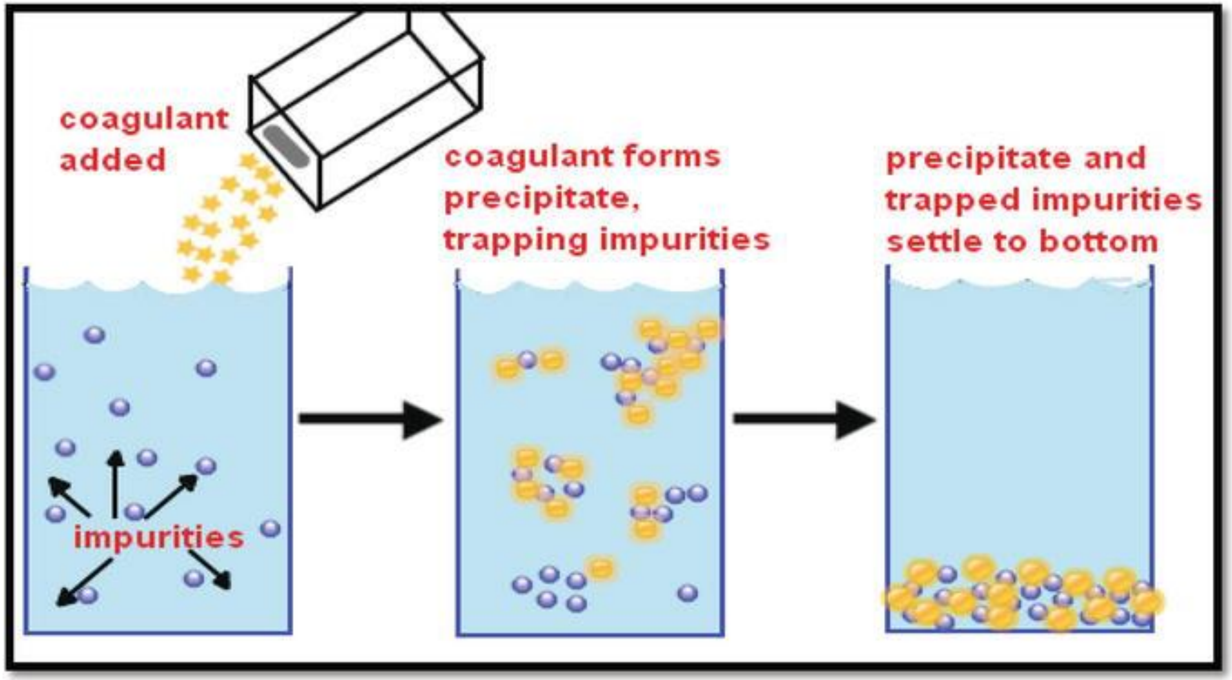


Fig 6 – Action of coagulants

Tetteh, E.K. and Rathilal, S., 2019. Application of organic coagulants in water and wastewater treatment. IntechOpen.

Common coagulants

- Alum: $Al_2(SO_4)_3 \cdot 14H_2O$
- Aluminum chloride: $AlCl_3$
- Ferric chloride: $FeCl_3$
- Ferric sulfate: $FeSO_4$
- Polyaluminum chloride (PACl): $Al_w(OH)_xCl_{3w-x}$
- Polyaluminum sulfate (PAS) $Al_x(OH)_y(SO_4)_z$
- Polyelectrolytes

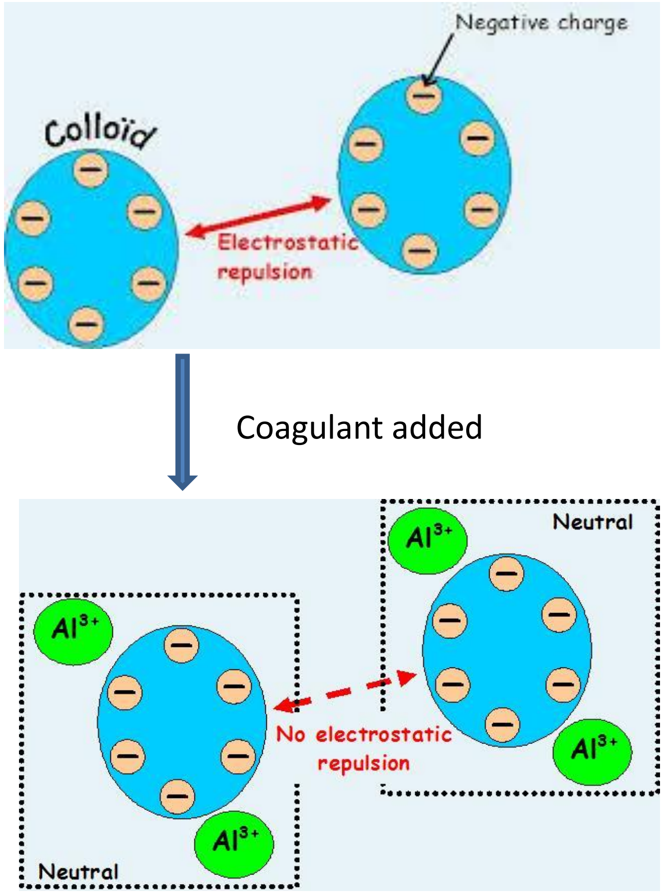


Fig 7 – Action of Al based coagulants

https://www.thewatertreatments.com/wastewater-sewage-treatment/coagulation-types/

Flocculation

Aggregation of destabilized particles into larger masses that easier to remove from water than the original particles without adding chemical to the treatment.

(Howe, K.J., Hand, D.W., Crittenden, J.C., Trussell, R.R. and Tchobanoglous, G., 2012. Principles of water treatment. John Wiley & Sons.)

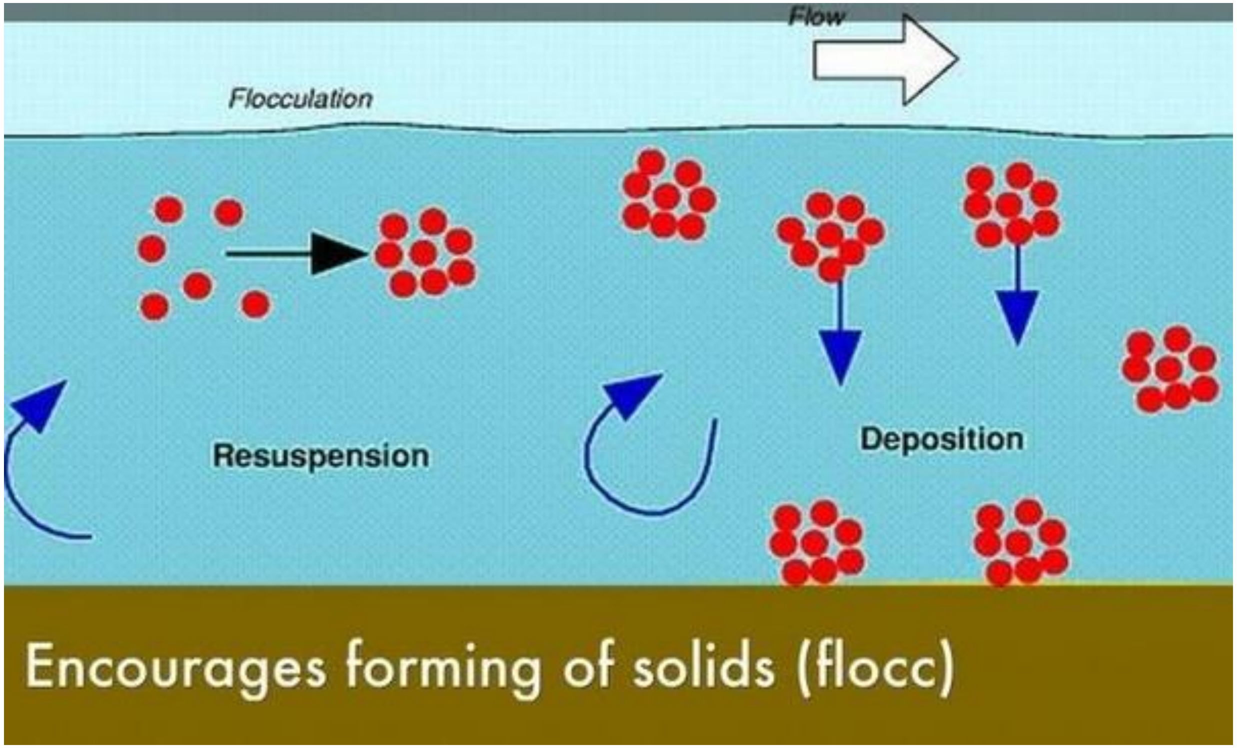


Fig 8 – Schematic diagram of Flocculation

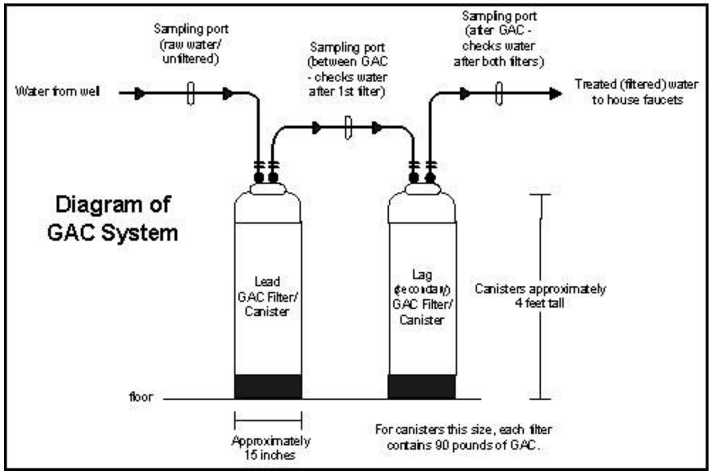
(http://techalive.mtu.edu/meec/module03/DrinkingWaterProcess.html)

GAC (Granular Activated Carbon) filtration

- GAC particles contain 0.2-5 mm in diameter, are a char of carbon material (wood or coal).
- They are ‘activated’ or made more porous by exposure to steam at high temperature.
- Activated carbon has 1000 m^2 of adsorbing surface area per gram (i.e.: equivalent to that of a 40 acre farm in one handful)
- It can be used for the increment of the efficiency of microplastic removal from water

(Wang, Z., Lin, T. and Chen, W., 2020. Occurrence and removal of microplastics in an advanced drinking water treatment plant (ADWTP). Science of The Total Environment, 700, p.134520.)

Fig 9 – Schematic diagram of GAC filtration instrument



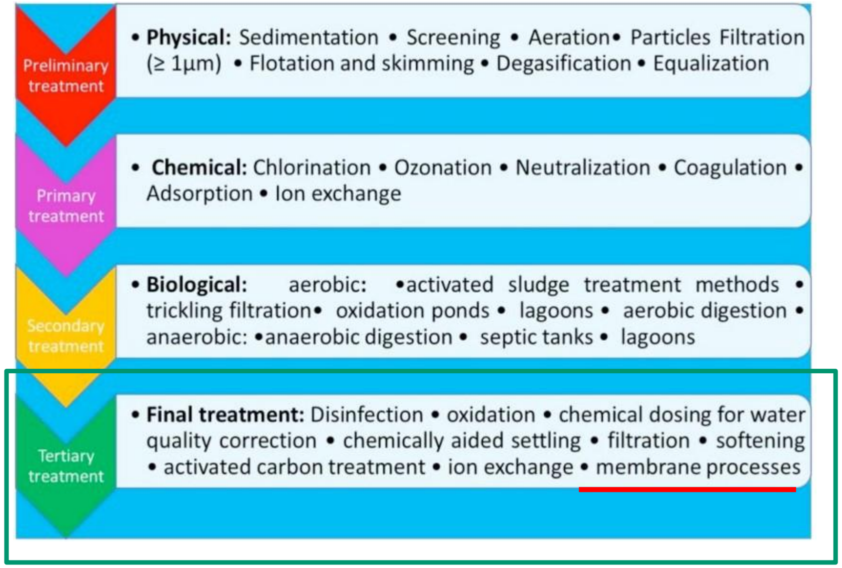
https://www.health.state.mn.us/communities/environment/hazardous/topics/gac.html#types

The technologies for microplastics removal

Microplastics Removal

The wastewater processing for plastic pollution can be grouped into four main treatments:

- ✓ preliminary treatment,
- ✓ primary treatment,
- ✓ secondary treatment,
- ✓ and tertiary treatment or advanced treatment.



Preliminary treatment
- **Physical:** Sedimentation • Screening • Aeration• Particles Filtration (≥ 1µm) • Flotation and skimming • Degasification • Equalization

Primary treatment
- **Chemical:** Chlorination • Ozonation • Neutralization • Coagulation • Adsorption • Ion exchange

Secondary treatment
- **Biological:** aerobic: •activated sludge treatment methods • trickling filtration• oxidation ponds • lagoons • aerobic digestion • anaerobic: •anaerobic digestion • septic tanks • lagoons

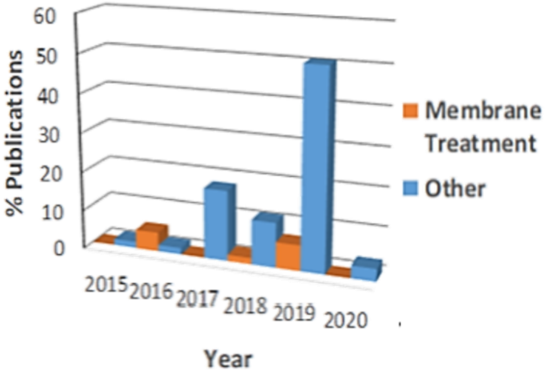
Tertiary treatment
- **Final treatment:** Disinfection • oxidation • chemical dosing for water quality correction • chemically aided settling • filtration • softening • activated carbon treatment • ion exchange • membrane processes

ADVANCED TECHNOLOGIES

The tertiary treatments included different filtering (sand and cloth), flotation techniques and membrane processes.

- ✓ Micro-screen filtration with discfilters (DF)
- ✓ Rapid (gravity) sand filters (RSF)
- ✓ Dissolved Air Flotation (DAF)
- ✓ Membrane bioreactor (MBR)

The distribution of publications related to microplastic contaminant removal from 2015 to 2020.



The technologies for microplastics removal

Microplastics Removal

ADVANCED TECHNOLOGIES

✓ Micro-screen filtration with discfilters (DF)

The process is based on primary clarification, conventional activated sludge (CAS) process and a tertiary denitrifying biological filter (BAF).

✓ Membrane bioreactor (MBR)

The MBR pilot included Submerged Membrane Unit (SMU) and ultrafiltration (UF) process. During the filtration, the water is forced through membranes under negative pressure created by pumps and collected to the separate tank. MBRs are the combination of membrane filtrations processes with suspended growth biological reactors. This combination treats primary effluent containing suspended solids as well as dissolved organic matter and nutrients. Hence the MBR technology replaces secondary clarifiers in CAS systems.

✓ Dissolved Air Flotation (DAF)

In DAF, water is saturated with air at high pressure and then pumped to a flotation tank at 1 atm, forming dispersed water. The released air bubbles in dispersed water adhere to the suspended solids causing them to float to the surface, from where it is removed by skimming. Before the flotation, flocculation chemical Polyaluminium Chloride (PAX) is added to the wastewater with dosage of 40 mg/L to enhance flocculation. Before the DAF, the process is based on CAS process.

✓ Rapid (gravity) sand filters (RSF)

In RSF, the wastewater is filtered through a layer of sand. The sand filter composed of 1 m of gravel with gain size of 3e5 mm and 0.5 m of quartz with grain size 0.1e0.5 mm. Apart from physical separation removing suspended solids, adhesion by microbes removes nutrients and microbes. Before the sand filter the process is based on CAS method.

The technologies for microplastics removal

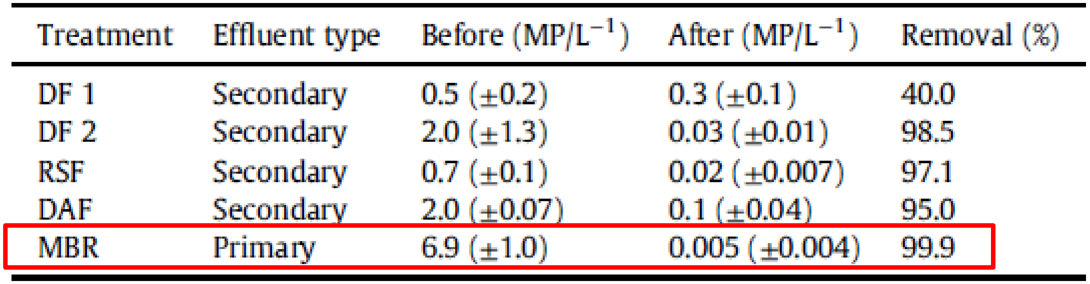
Microplastics Removal

ADVANCED TECHNOLOGIES

- ✓ Micro-screen filtration with discfilters (DF)
- ✓ Dissolved Air Flotation (DAF)
- ✓ Rapid (gravity) sand filters (RSF)
- ✓ Membrane bioreactor (MBR)

case study

The average microplastic concentrations before and after the treatments.



Treatment	Effluent type	Before (MP/L^{-1})	After (MP/L^{-1})	Removal (%)
DF 1	Secondary	0.5 (±0.2)	0.3 (±0.1)	40.0
DF 2	Secondary	2.0 (±1.3)	0.03 (±0.01)	98.5
RSF	Secondary	0.7 (±0.1)	0.02 (±0.007)	97.1
DAF	Secondary	2.0 (±0.07)	0.1 (±0.04)	95.0
MBR	Primary	6.9 (±1.0)	0.005 (±0.004)	99.9

DF10: discfilter with pore size 10 mm, DF 20: discfilter with pore size 20 mm, RSF: rapid sand filters, DAF: dissolved air flotation and MBR: membrane bioreactor.
Data is given in number of microplastics per liter of effluent

advantages of MBR:

1. With the MBR technology,MP concentration decreased from 6.9 (±1.0) to 0.005 (±0.004) MP L1. The MBR treats primary clarified wastewater with much higher MP concentration compared to secondary effluent, giving higher removal percentage than tertiary treatments.

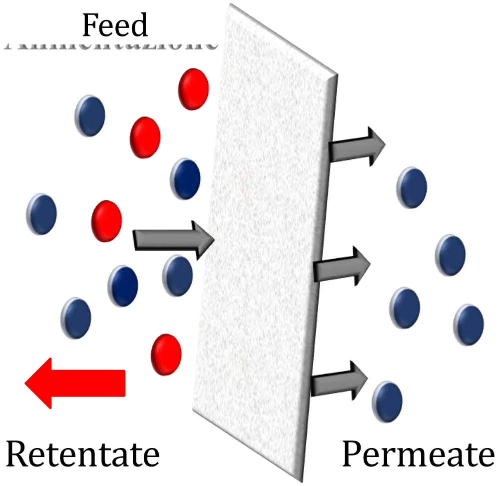
2. MBR gave also the lowest MP concentration of the final effluent, which indicates, that MBR is the most efficient technology in this study to remove MPs from wastewater. The result is expected as the MBR filters had the smallest pore size (0.4 mm) of for all the studied filters.

The membrane technology for microplastics removal

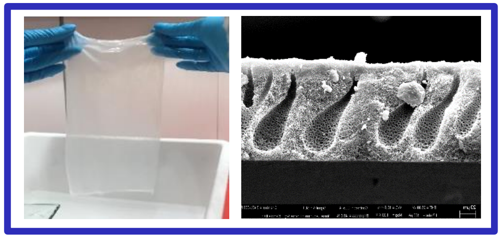
Microplastics Removal

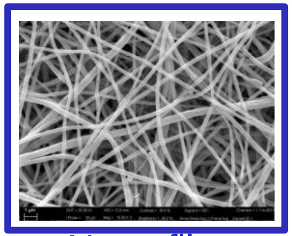
What is a membrane?

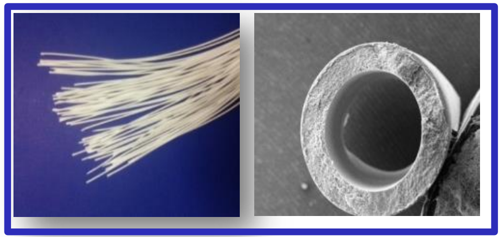
A membrane can be defined as a selective active barrier for particles transport between two adjacent phases regulating by the specific particle sizes and the molecular weights of the components.

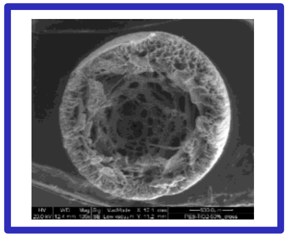


Membrane types:


Flat sheet


Nano-fiber


Hollow fiber


Spherical

The membrane technology for microplastics removal

Classification:

Membrane materials

Morphology[1]

Asymetric or anisotropic

Composite
(with skin 0.1-0-5 μm)

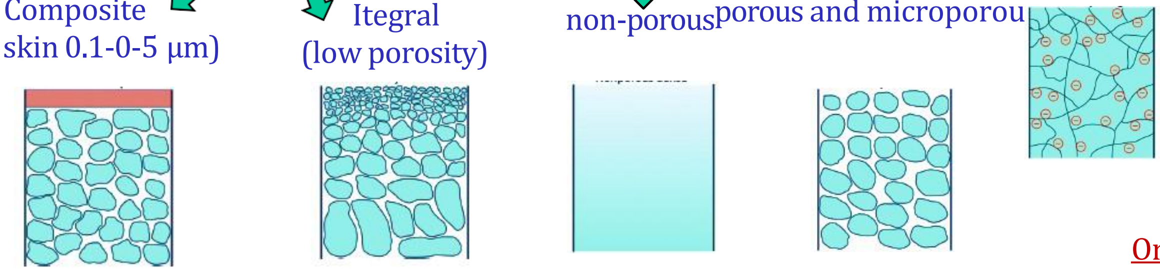
Itegral
(low porosity)

Symetric or isotropic

non-porous

porous and microporou

ion-exchange



State

amorphous

semicrystalline

crystalline

Origin

natural

organic
(bio-polymers)

inorganic

artificial

inorganic

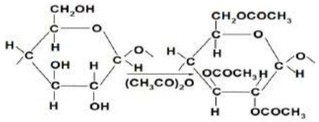
organic
(polymeric)

glassy

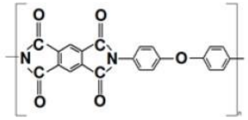
The membrane technology for microplastics removal

Membrane materials

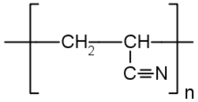
Polymers:



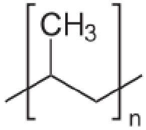
Cellulose acetate



Polyimide

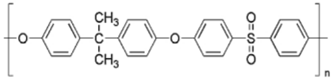


Polyacrylonitrile

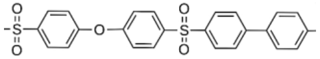


Polypropilene

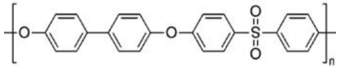
Sulfone-based polymers



Polysulfone



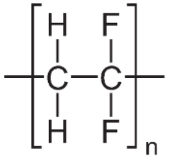
Polyether Sulfone



Polyphenyl Sulfone

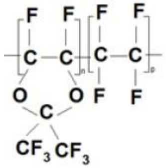
Good electrical properties
Good chemical resistance
Stable over a wide range of temperatures
High temperature resistance

Fluoropolymers



High Performance in term of chemical and mechanical stability.

Polyvinylidene difluoride (PVDF)



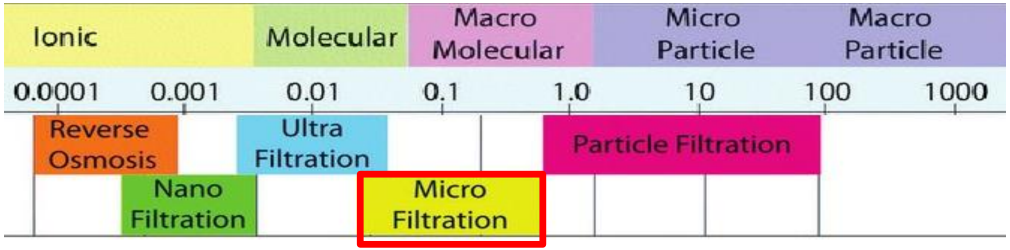
Teflon

The membrane technology for microplastics removal

Membrane filtration

The application of membrane technology for micro-plastics removal has been also studied because membrane is suitable to remove low-density/poorly settling particles.

Membrane filtration spectrum

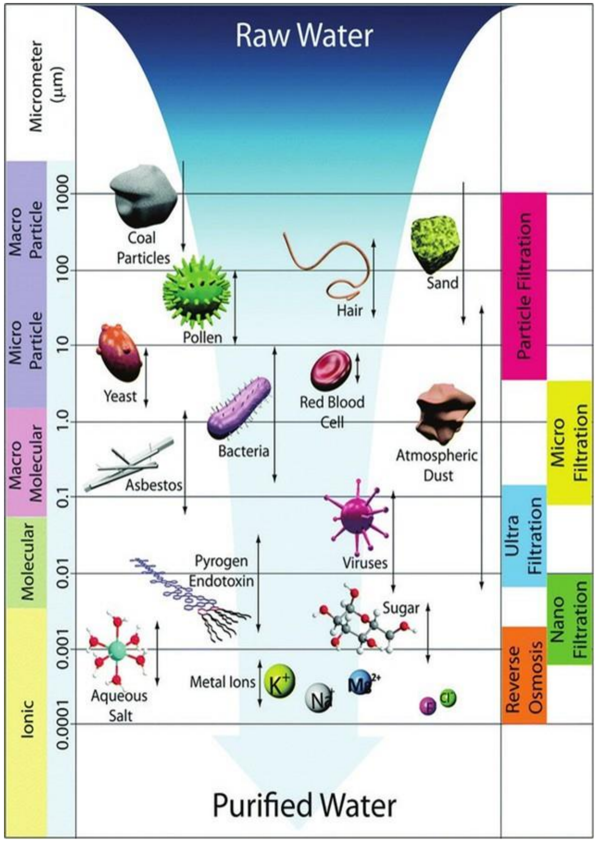


Membranes

- PORE SIZE : 0.2-0.4 µm
- PREPARATION TECHNIQUE: phase inversion
- Mostly direct interception capture at membrane surface.
- Secondary mechanisms of capture.

Filters

- PORE SIZE : > 0.2-0.4 µm
- Particles retained by “Direct Interception.”



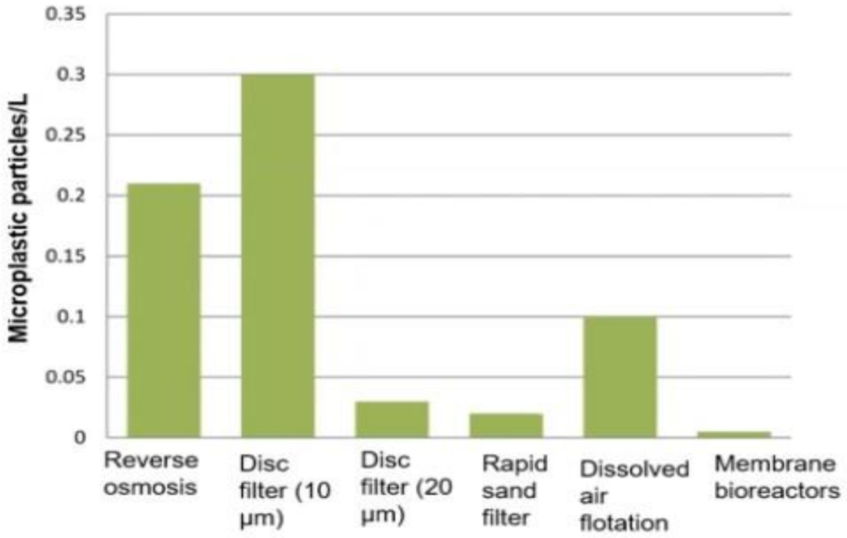
The membrane technology for microplastics removal

Membrane processes for MP removal

- ✓ Ultrafiltration (UF)
- ✓ Reverse Osmosis (RO)
- ✓ Membrane Bioreactor (MBR)

The shape of the plastic particles affects their removal efficiency in membrane watertreatment and can determine the interaction between other contaminants or microorganisms

The number of microplastic particles per liter in the final effluent of each wastewater treatment plant



(Data elaborated from Ziajahromi et al. 2017 and Talvitie et al. 2017)

The membrane technology for microplastics removal

Membrane processes for MP removal

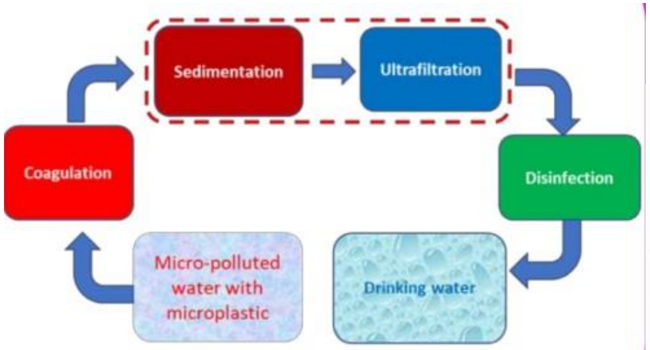
✓ Ultrafiltration (UF)

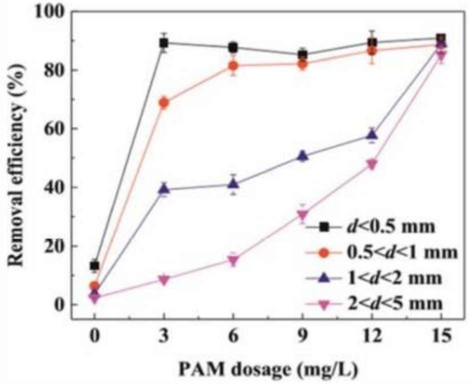
It is a low-pressure process (1–10 bar) that, using asymmetric UF membranes having a pore size between 1–100 nm.

UF, despite a broad molecular weight cut o (MWCO) range, is less active in removing low molecular weight organic matters. In many cases, UF is integrated into the process, using primary (flotation and filtration) and some secondary treatments as pretreatment stages and used for pre-filtration in reverse-osmosis plants to protect the reverse-osmosis process.

Study of microplastic removal by coagulation and UF process for the production of drinking water

The removal behavior of polyethylene (PE) in drinking water treatment by ultrafiltration and coagulation processes by using an Fe-based coagulant.





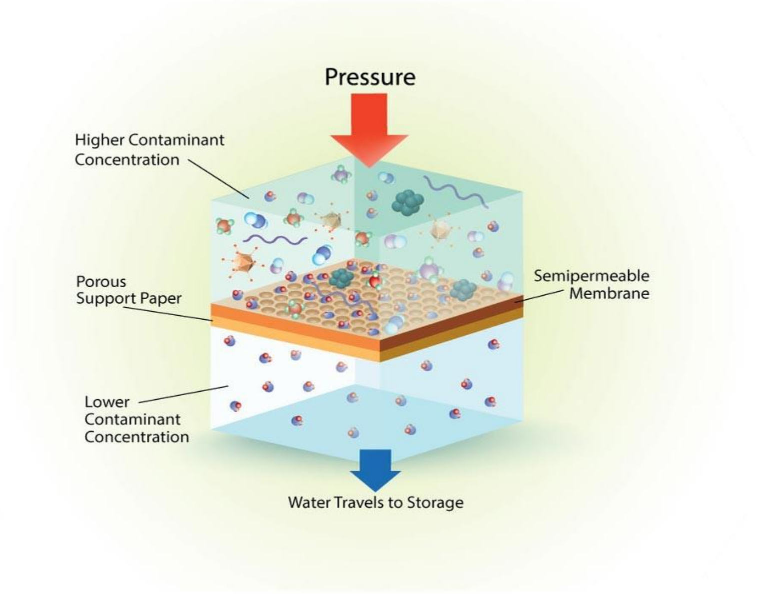
Low removal efficiency of PE particles (below 15%) was observed after coagulation, indicating the infectiveness of the sole coagulation process with respect to microplastic removal. However, when the Polyacrylamide (PAM) was added to enhance the coagulation performance, removal efficiency of small-particle-size PE (d < 0.5 mm) significantly increased from 13 to 91%.

The membrane technology for microplastics removal

Membrane processes for MP removal

✓ Reverse Osmosis (RO)

Reverse Osmosis (RO), is actually used in municipal and industrial water treatment systems to purify water using nonporous or nanofiltration membranes (pore size > 2 nm) by removing salts, contaminants, heavy metals, and other impurities. It works by applying a high pressure (10–100 bar) to a concentrated water solution that forces the water through a semipermeable membrane, leaving all the other substances essentially in a more concentrated water solution.



Disadvantages

- Fuouling
- Scaling
- Need of pre-treatment steps

Most of the more performant applications of RO in the microplastic removal are obtained when coupled with membrane bioreactor technology.

The membrane technology for microplastics removal

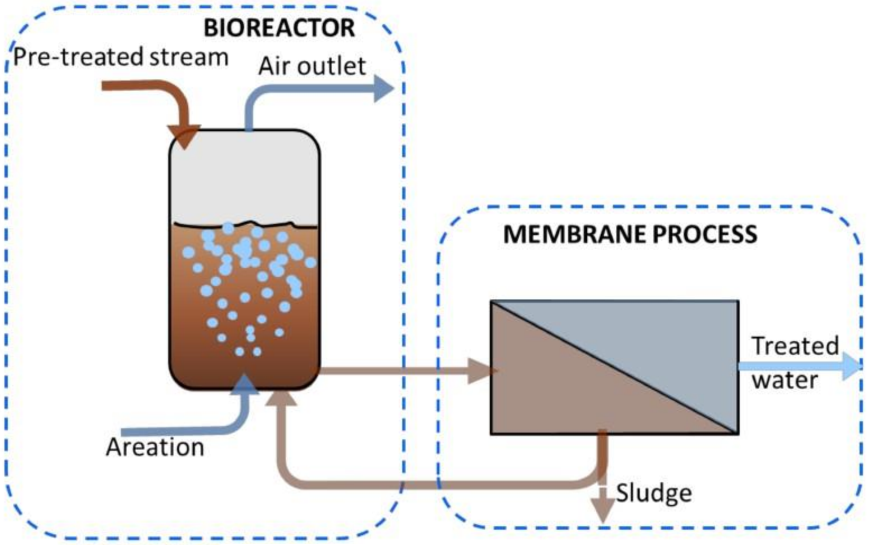
Membrane processes for MP removal

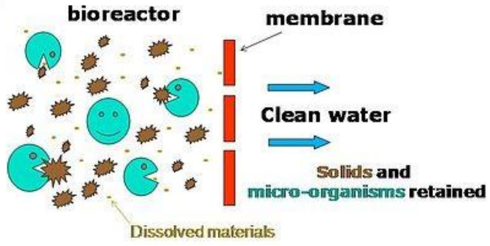
- ✓ Membrane Bioreactor (MBR)

Membrane bioreactor (MBR) are systems in which catalysis promoted by biological catalysts (bacteria, enzymes), is coupled to a separation process, operated by a membrane system (generally microfiltration or ultrafiltration).

In MP treatment, the role of MBR is the decrease of solution complexity by the biodegradation of the organic matter; this will permit the purification of MP and its further treatment. The process generally starts when a pre-treated streams enters in the bioreactor, where the process of biodegradation of organic matter is carried out. The produced mixed liquor is then pumped along with semi-crossflow filtration system for the separation process. Thanks to the membrane process, the MP is concentrated in the retentate stream.

Schematic representation of a MBR process






THANK YOU