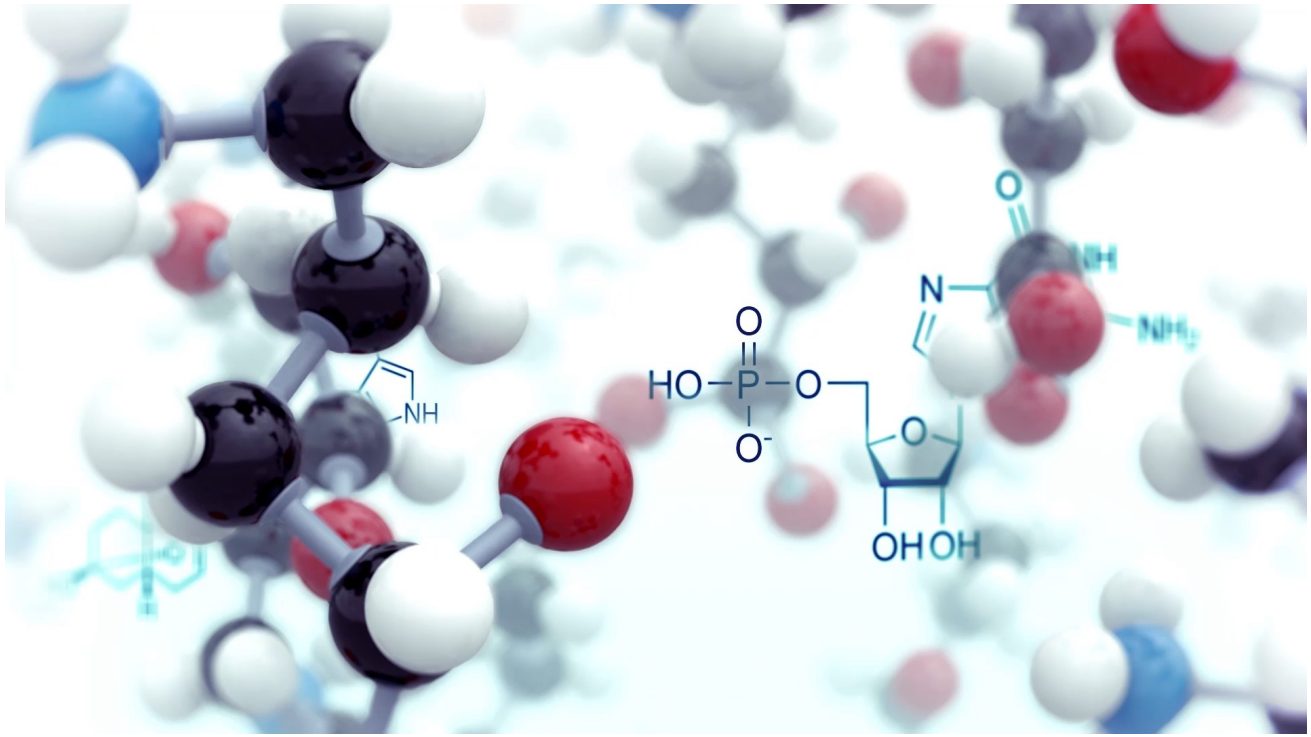
Risks of micro- en nanoplastics for human health

Raymond Pieters

Institute for Risk Assessment Sciences

Utrecht University



POLYRISK

Understanding human exposure and health hazard of micro- and nanoplastic contaminants in our environment

Dr. Raymond Pieters (Utrecht University)

The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

Microplastics and Cardiovascular Diseases: Importance of Coexisting Environmental Pollutants

Duk-Hee Lee, MD, PhD

Circulation. 2024;150:908–910. DOI: 10.1161/CIRCULATIONAHA.124.069801

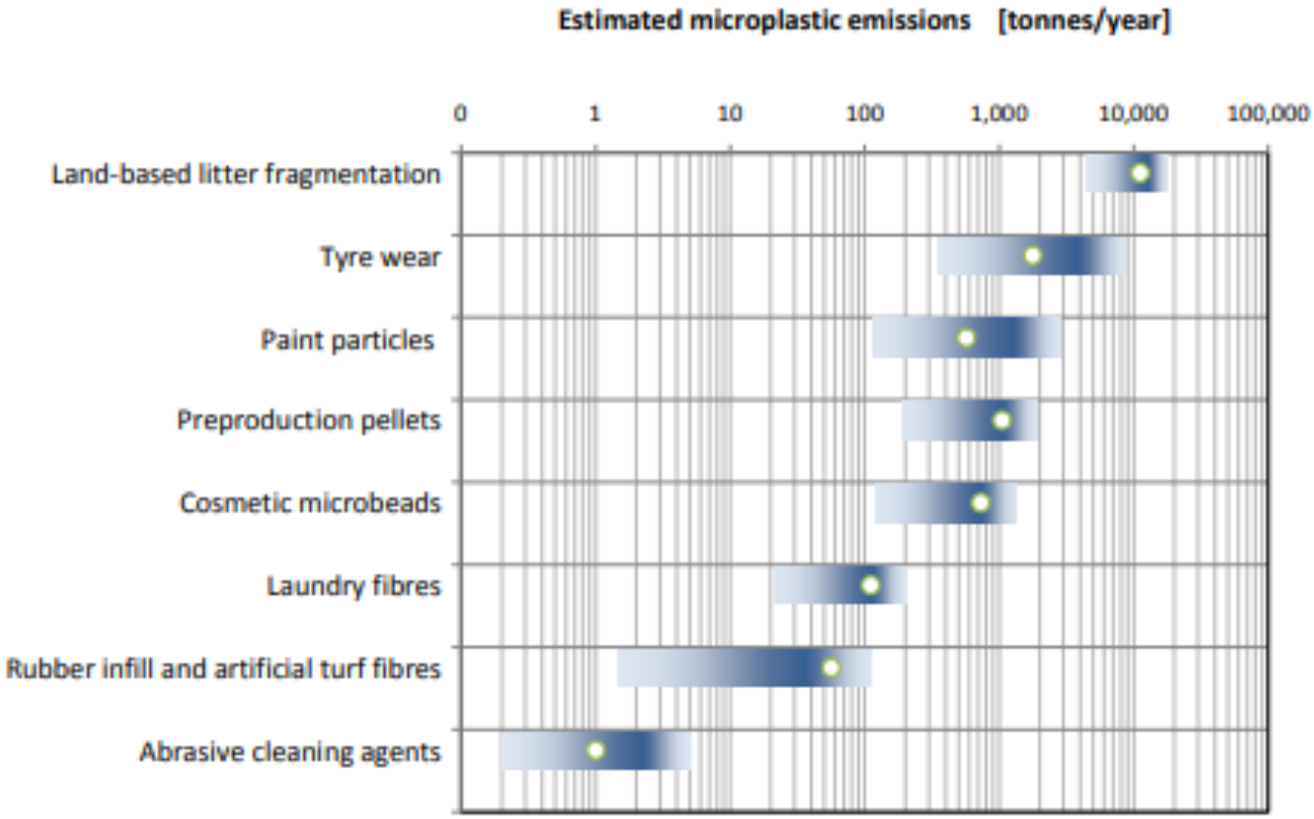
Haixiang Zheng[4,6], Gianpaolo Vidili[7], Gavino Casu[7],
Eliano Pio Navarese[4], Leonardo A. Sechi[2,5] and Youren Chen[1]*

Emerging Links Between Cardiovascular Disease and Microplas

Emily Gu BA[1], Brian Devorkin BS[2], Melinda Chu MD, MBA[3]

[1]Yale School of Medicine, New Haven, Connecticut, USA
[2]Case Western Reserve University School of Medicine, Cleveland, Ohio, USA
[3]Ecotera Health, Cincinnati, Ohio, USA

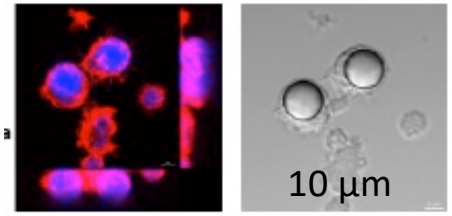
Microplastics emissions in the Netherlands



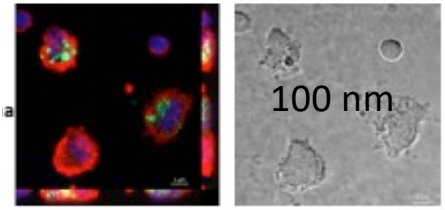
https://www.rivm.nl/publicaties/potential-measures-against-microplastic-emissions-to-water

Size comparisons

Microplastics < 1-5 mm
or < 1 mm



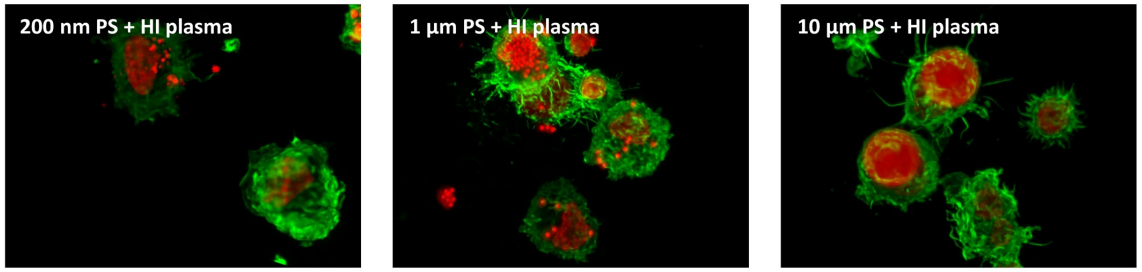
Nanoplastics < 100 nm



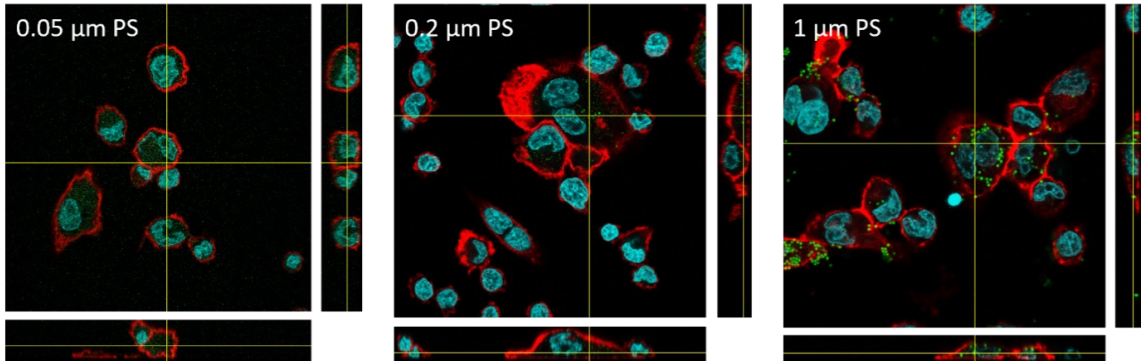
Diameter pinhead	1 mm
Diameter human's hair	80 µm (60-120)
Length of sperm's tail	50 µm
Diameter macrophage	21 µm
Diameter human's egg cell	20 µm
Diameter dendritic cell	10-15 µm
Thickness alu-foil	10 µm
Diameter bacteria	2 µm
Thickness of soap bubble	750 nm
Length of virus	100 nm (size 20-500 nm); (SARS-CoV-2: 60-140nm)
Thickness DNA molecule	2 nm
Diameter H-atom	0.1 nm

PS are taken up by monocyte derived dendritic cells and THP-1 macrophages

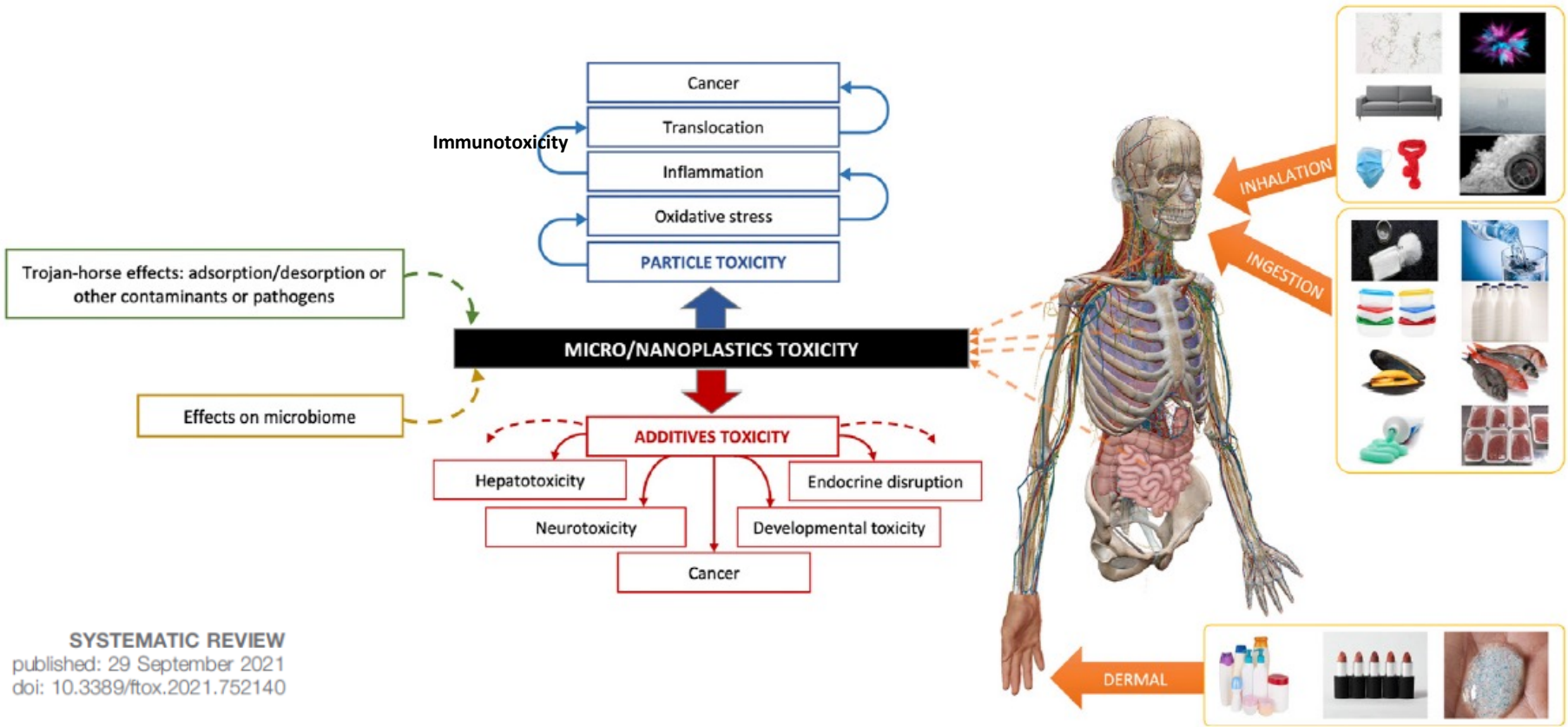
Dendritic Cells (human-monocyte derived)



Macrophage (PMA differentiated THP1, dTHP1)



Potential toxicities and exposure routes of MNP

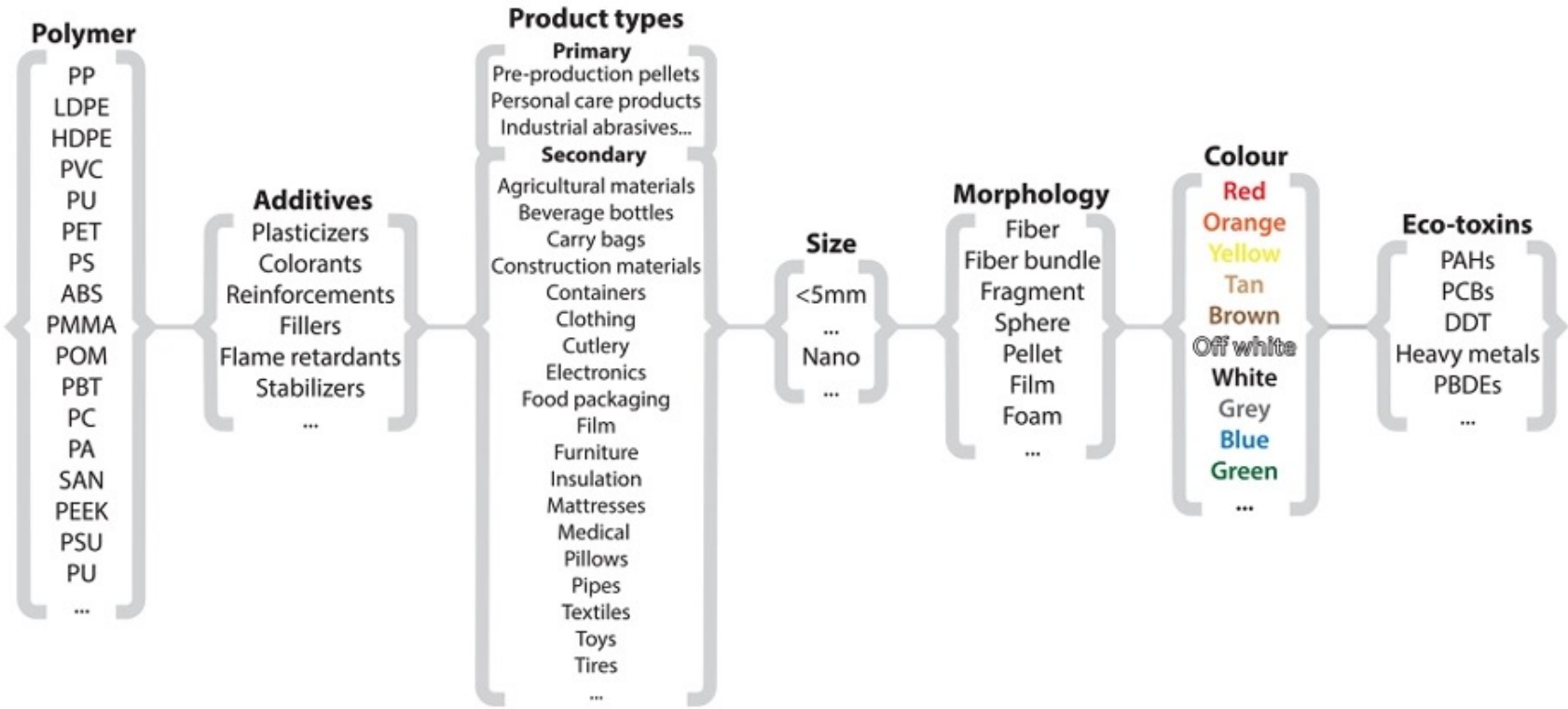


SYSTEMATIC REVIEW
published: 29 September 2021
doi: 10.3389/ftox.2021.752140

FIGURE 1 | Summary of the human routes of exposure to MNPLs and their potential effects on health.

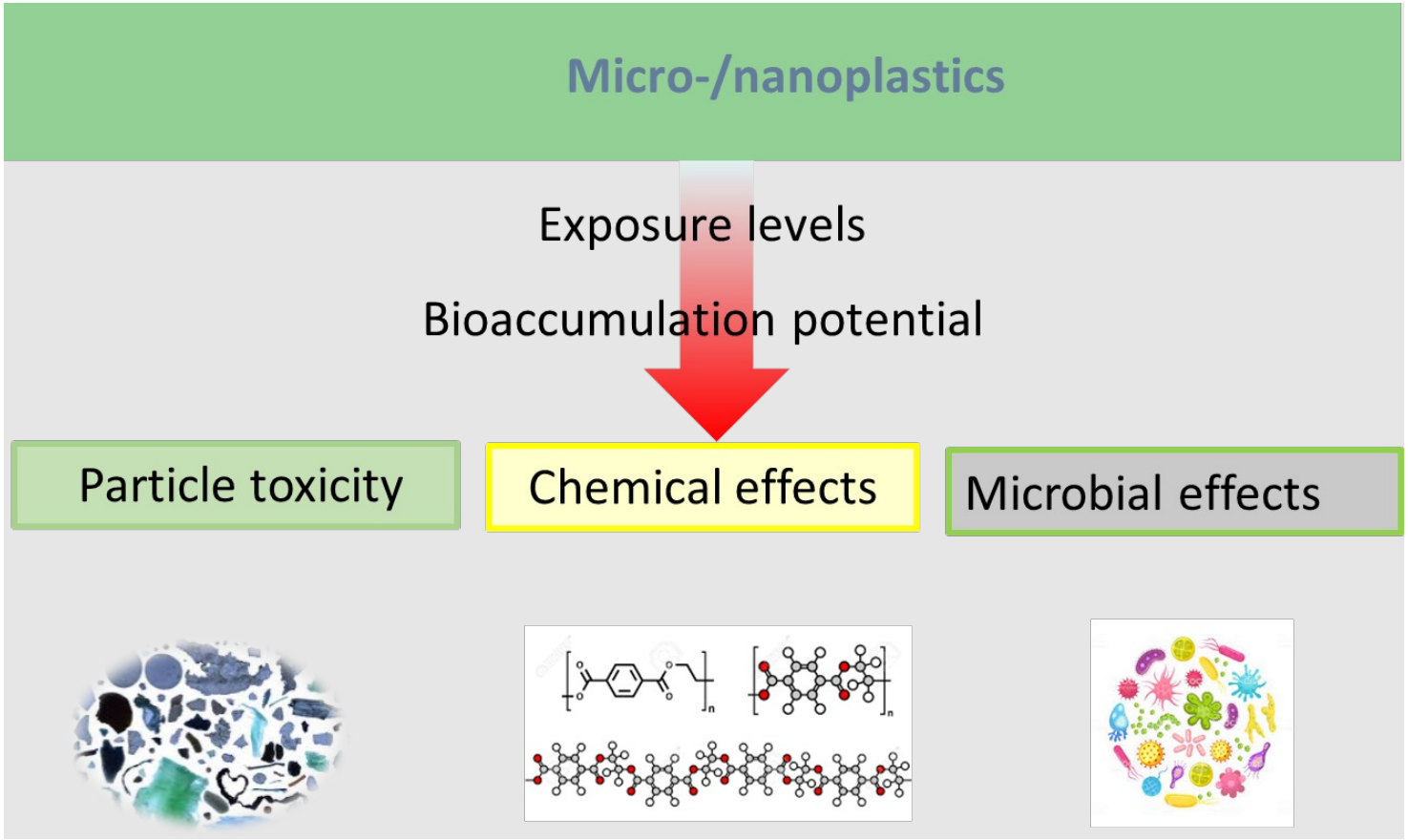
Micro-nanoplastics are extremely complex substances

Environmental Toxicology and Chemistry—Volume 38, Number 4—pp. 703–711, 2019



Additives: phtalates/bisphenol/pesticides/PFAS/catalysts/heavy metals: endocrine/immunotoxicants

Potential effects of micro- and nanoplastics



POLYRISK

Understanding human exposure and health hazard of micro- and nanoplastic contaminants in our environment

RISK = HAZARD * EXPOSURE

RISK = TOXIC EFFECT * CONCENTRATION (AT TARGET)

Is there a risk for humans?
What do we need to know?

General Risk Assessment Paradigm

Substance Identity
What shall be assessed? One substance? A mixture? (Nano-)particles?

Exposure Assessment
For whom? (general public, worker, consumer, patients)?
Exposure route? Dose, duration, frequency?

Hazard Identification
What **adverse effects** are caused?
Target organ(s)?

Hazard Characterization
Dose- Response? Threshold?

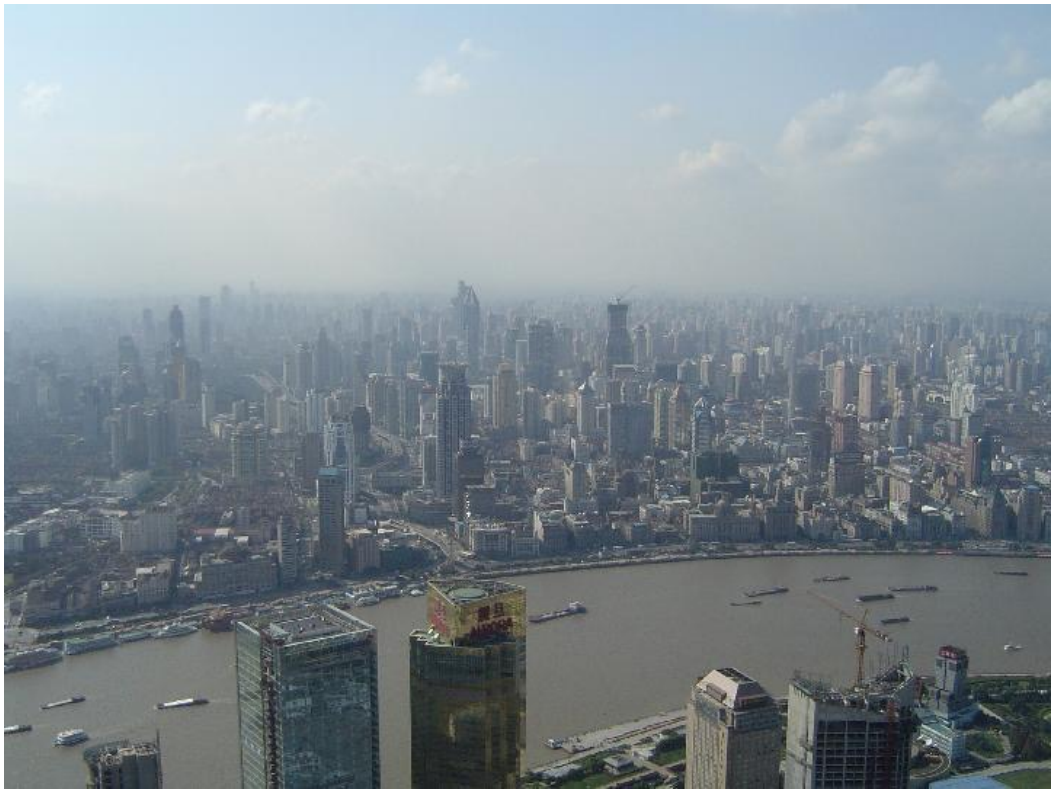
Risk characterization
Is there a risk? For whom? How big is the risk?

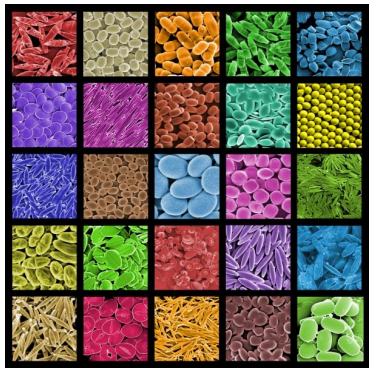
Challenges for MNPs

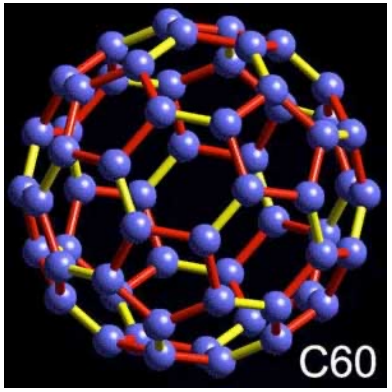
- **Heterogeneous class of particles**: different polymer types, broad spectrum of physicochemical properties, additional contaminants, …
- **Lack of reliable methods**: in particular, many analytical challenges (nano vs micro, water vs other matrices…)
- **Lack of reliable data**: on adverse effects, on external/ internal exposure
- Discrepancy of investigated MNPs (type, size range, shape) compared to what is found in the environment; mostly **monodisperse polystyrene** particles investigated

WHO report (2022): current data and evidence indicate that MNPs may have adverse effects similar to those of other solid particles, and furthermore, share similar modes of action https://www.who.int/publications/i/item/9789240054608

What have we learned from toxicology induced by airborne particulate matter (PM) and nanoparticles?







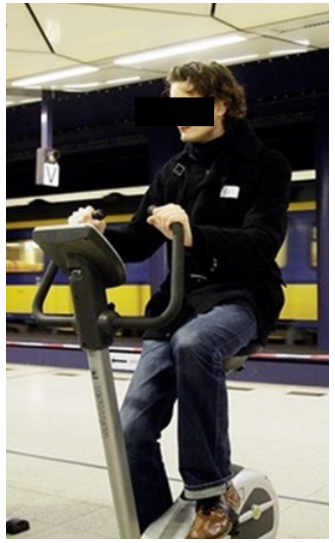
Previous human studies

RESEARCH ARTICLE

Inhal Toxicol, 2014; 26(3): 141–165

Air pollution exposure affects circulating white blood cell counts in healthy subjects: the role of particle composition, oxidative potential and gaseous pollutants – the RAPTES project

Maaike Steenhof[1], Nicole A. H. Janssen[2], Maciej Strak[1,2]*, Gerard Hoek[1], Ilse Gosens[2], Ian S. Mudway[3], Frank J. Kelly[3], Roy M. Harrison[4,5], Raymond H. H. Pieters[1], Flemming R. Cassee[1,2], and Bert Brunekreef[1,6]



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Volunteers on ergometer

Outdoor: Urban background; Continuous traffic; Stop-and-go; Farm…

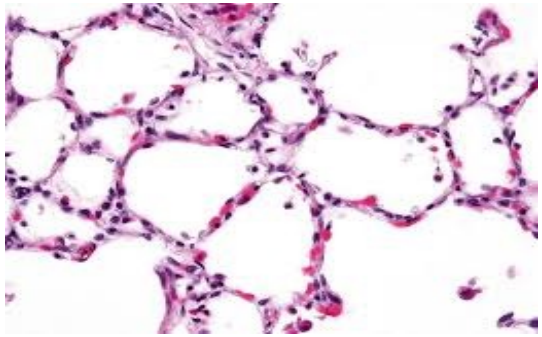
Table 4. Descriptive statistics: percentage change in blood cell counts over baseline.

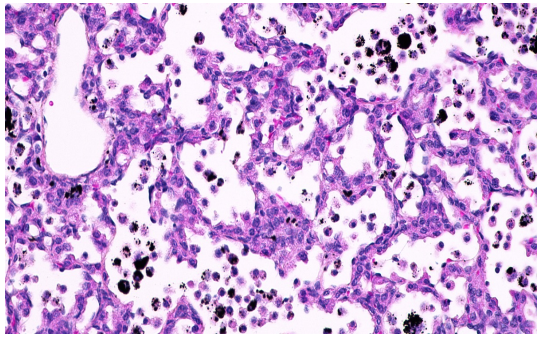
	Percentage change over baseline[a] (95% CI)		
	All sites (n = 167/166)	Outdoor sites (n = 124/122)	Underground (n = 43/44)
Total WBC			
2 h PE	15.0 (11.8; 18.4)	10.5 (7.1; 14.1)	25.9 (18.6; 33.6)
18 h PE	−10.4 (−12.7; −8.1)	−12.2 (−14.3; −10.0)	−4.9 (−10.6; 1.2)
Neutrophils			
2 h PE	35.0 (29.3; 41.0)	31.0 (25.1; 37.2)	49.2 (34.8; 65.2)
18 h PE	−2.0 (−5.5; 1.7)	−3.0 (−6.8; 1.1)	1.0 (−7.6; 10.4)
Monocytes			
2 h PE	−11.3 (−19.8; −1.9)	−15.6 (−25.4; −4.6)	4.1 (−10.4; 20.9)
18 h PE	−12.2 (−14.8; −9.5)	−13.9 (−16.9; −10.8)	−6.8 (−12.0; −1.2)
Lymphocytes			
2 h PE	−6.8 (−10.0; −3.4)	−6.8 (−10.2; −3.2)	−5.8 (−14.4; 3.6)
18 h PE	−21.3 (−23.5; −19.1)	−22.9 (−25.2; −20.5)	−17.3 (−21.7; −12.6)
Eosinophils			
2 h PE	−35.6 (−43.4; −26.8)	−36.9 (−46.1; −26.1)	−31.6 (−42.9; −18.0)
18 h PE	−12.2 (−16.8; −7.3)	−13.9 (−19.5; −7.9)	−5.8 (−12.8; 1.7)

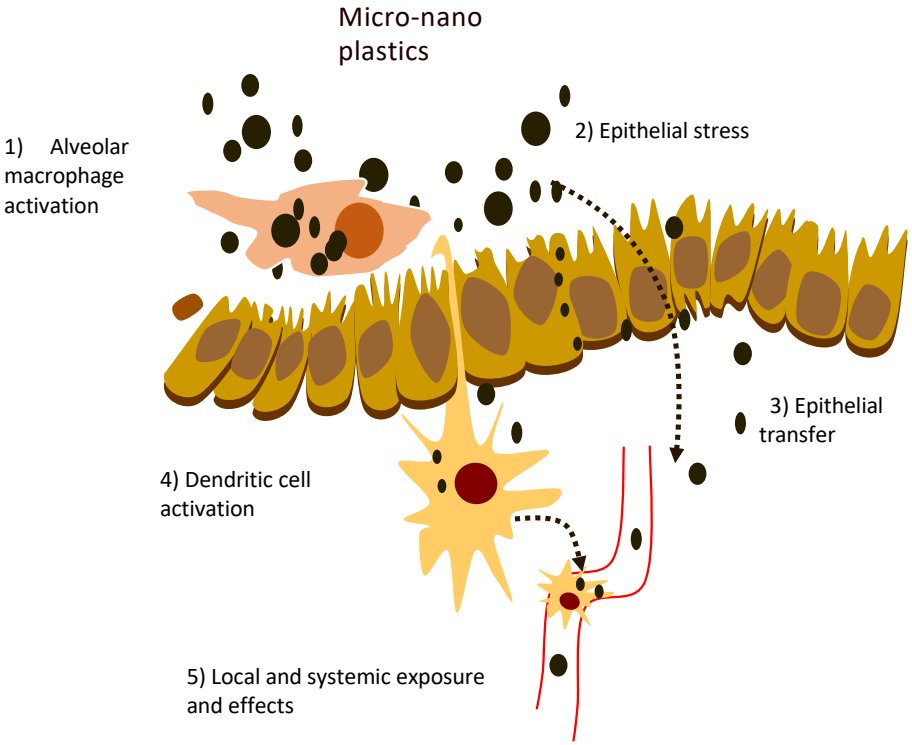
CI = confidence interval; h = hours; n = number of observations for total cell counts 2 h PE/18 h PE; PE = post exposure; WBC = white blood cells.

[a]Calculated by using log-normalized cell counts. Cell counts are expressed as 10^9 cells/L.

Local effects and epithelial transfer of particulates

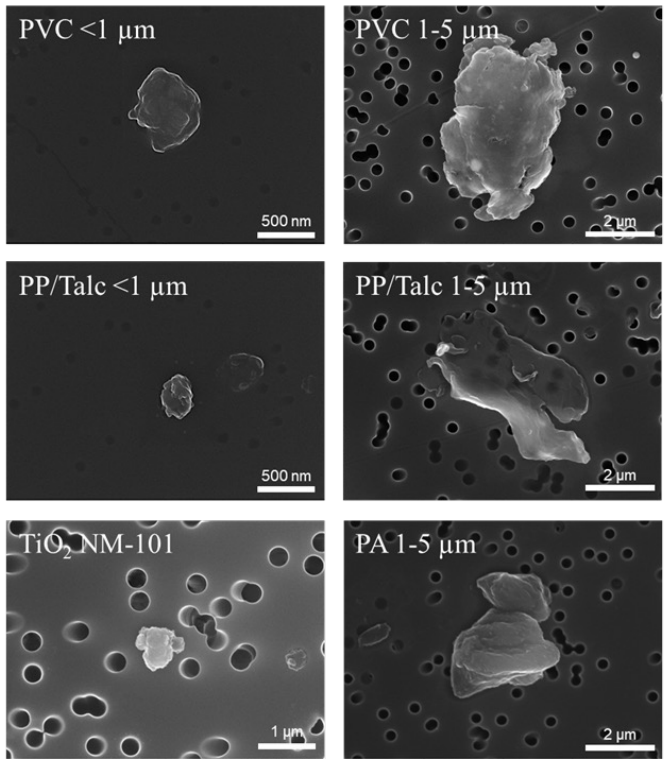






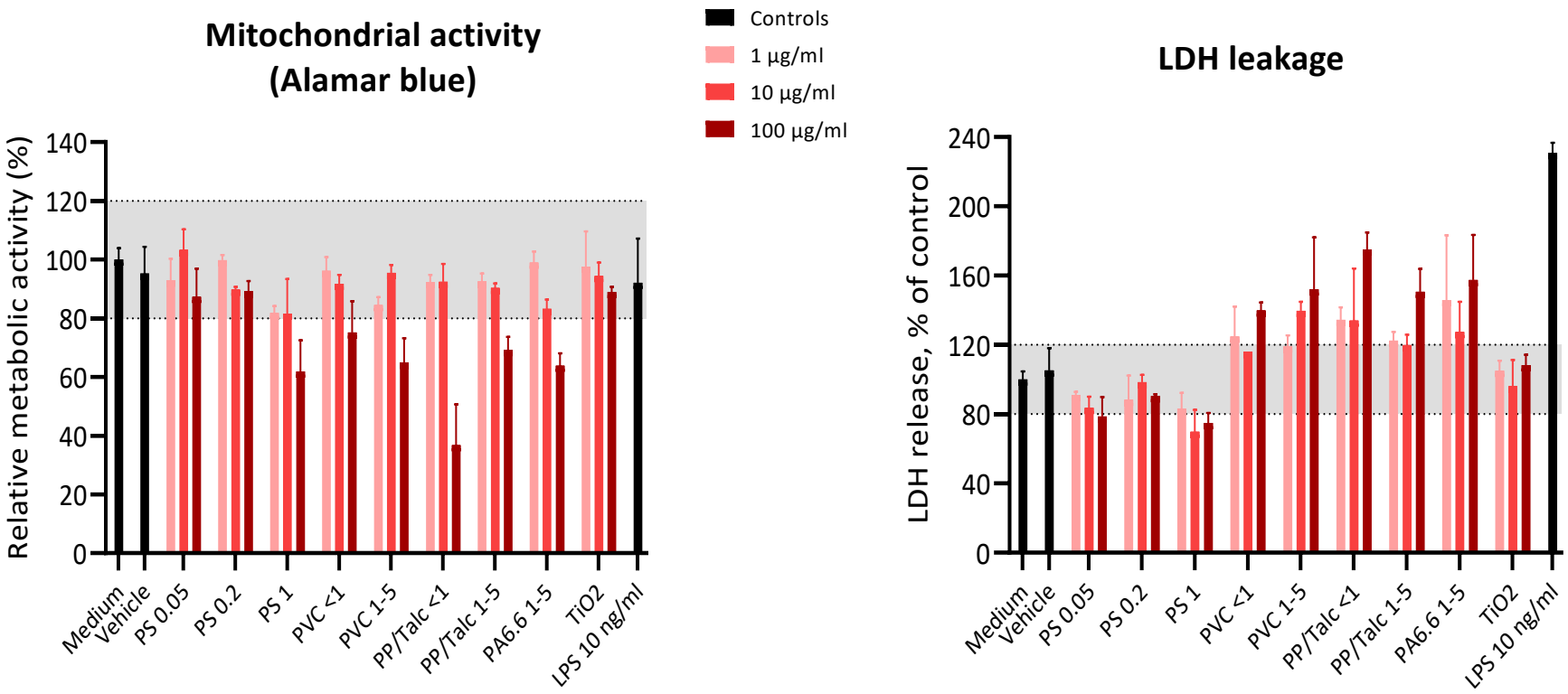
Effects of *secondary* MNP on dTHP1 macrophages *(produced top down (i.e. cryomilling etc)*

Particle type	Size (µm)
PS (polystyrene)	0.05, 0.2 and 1
PVC (polyvinylchloride)	<1 and 1-5
PP (polypropylene)/Talc	<1 and 1-5
PA (polyamide/Nylon-6,6)	1-5
TiO2 (Titanium oxide, reference particle)	0.35
LPS (10 ng/ml, positive control)	



van den Berg AET, et al. Microplast-nanoplast. 2025;5(1):32.
doi: 10.1186/s43591-025-00138-5

Effects of secondary MNPs on dTHP1-macrophages: cellular activity and viability



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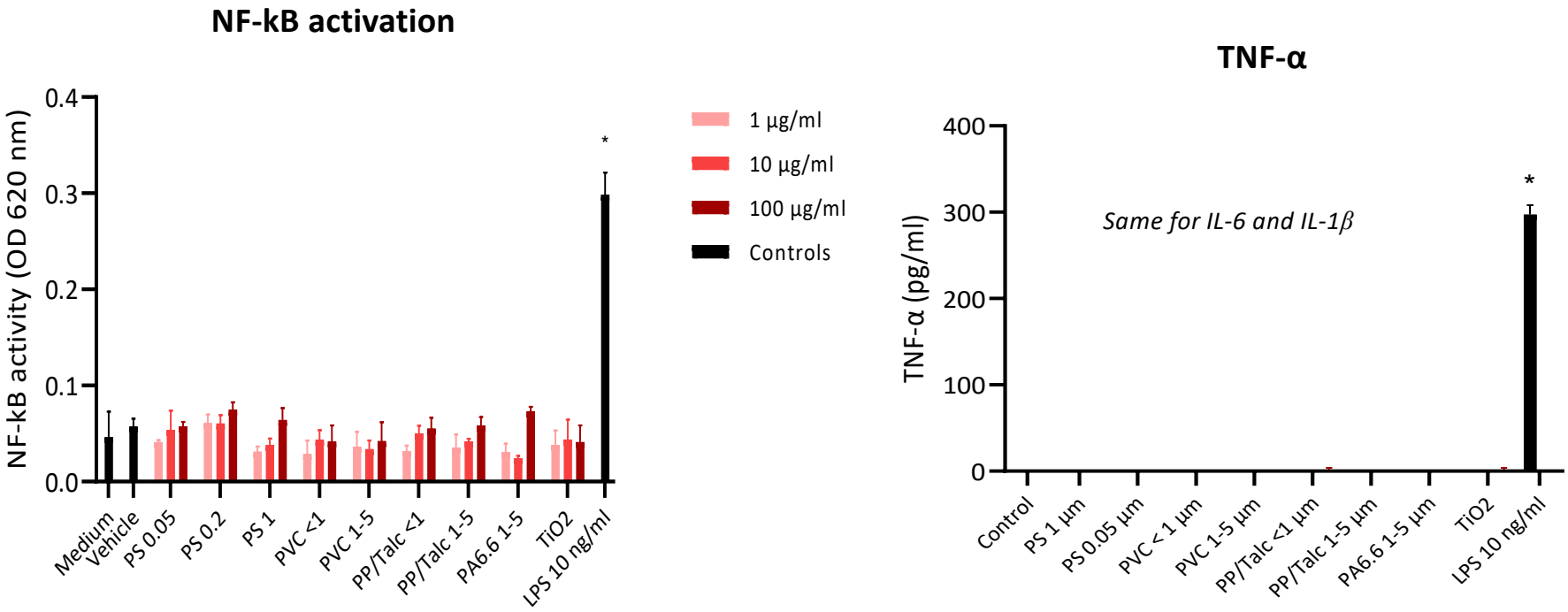

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doi: 10.1186/s43591-025-00138-5

MNPs appear (more) proinflammatory

when
-surface activated (oxidation),
-contaminated (e.g. microbial LPS)
or
-in context of proinflammatory mediators

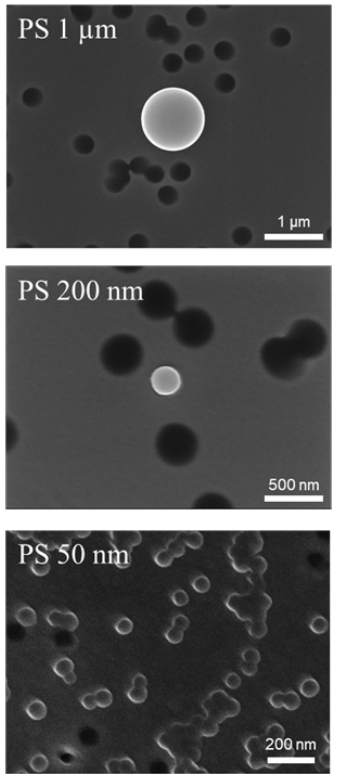
cellular uptake is increased by plasma proteins/components

Weathering determines immunotoxicological outcome of polystyrene MNPs

Primary PS beads

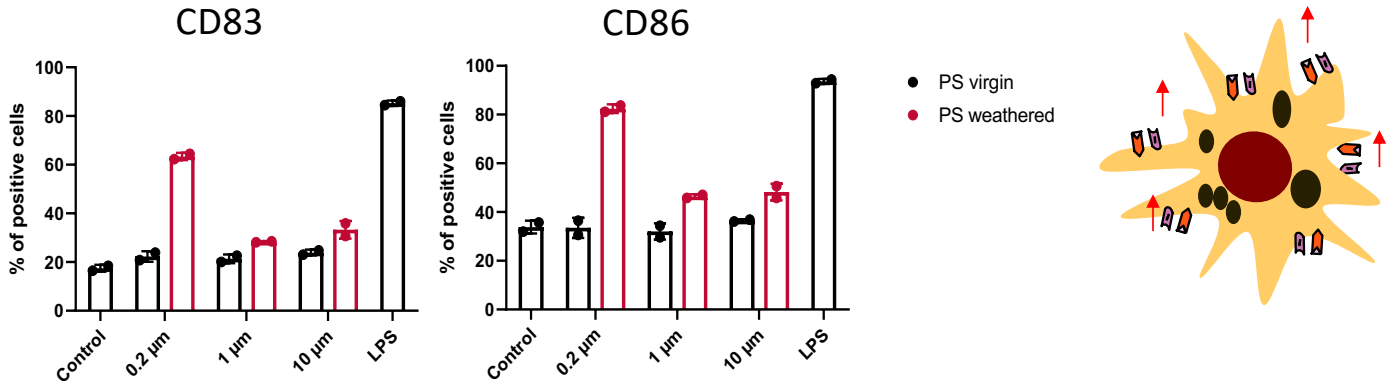
(commercial from polysciences)

- 0.05, 0.2, 1, 10 µm
- +/- environmental weathering: four weeks incubation in river water under constant shaking
- +/- pre-incubation with human HI plasma

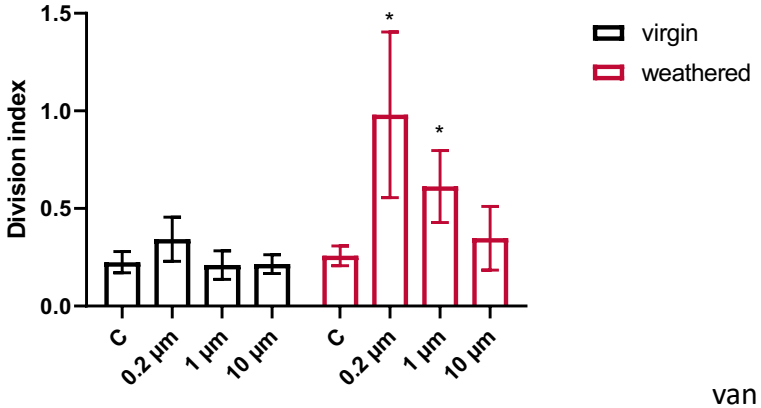


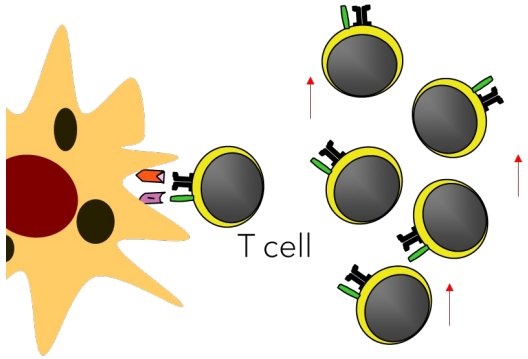
van den Berg AET, et al. J Immunotoxicol. 2022: 19:125-133.
doi: 10.1080/1547691X.2022.2143968.

Weathering determines immunotoxicological outcome of polystyrene MNPs in human Mo-DC



mixed leukocyte response: CD8





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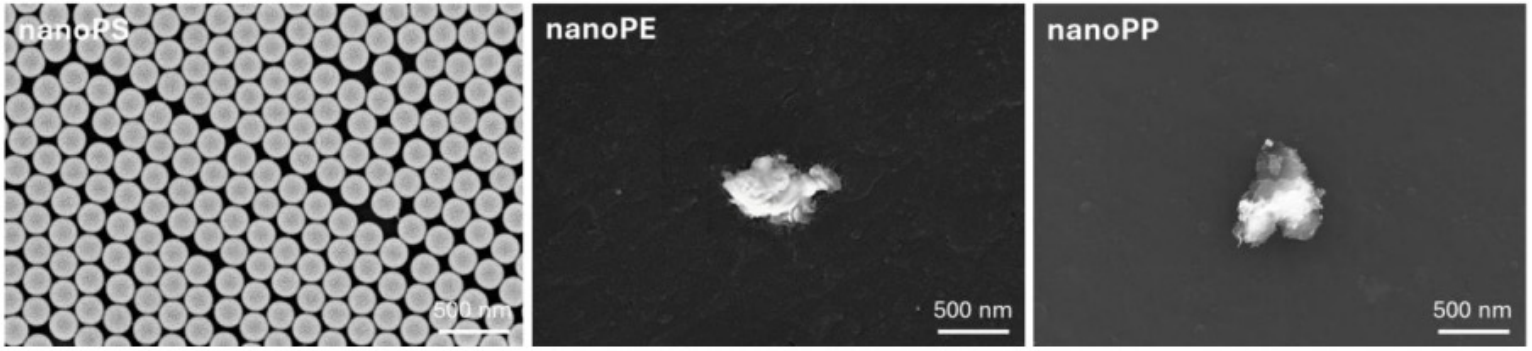
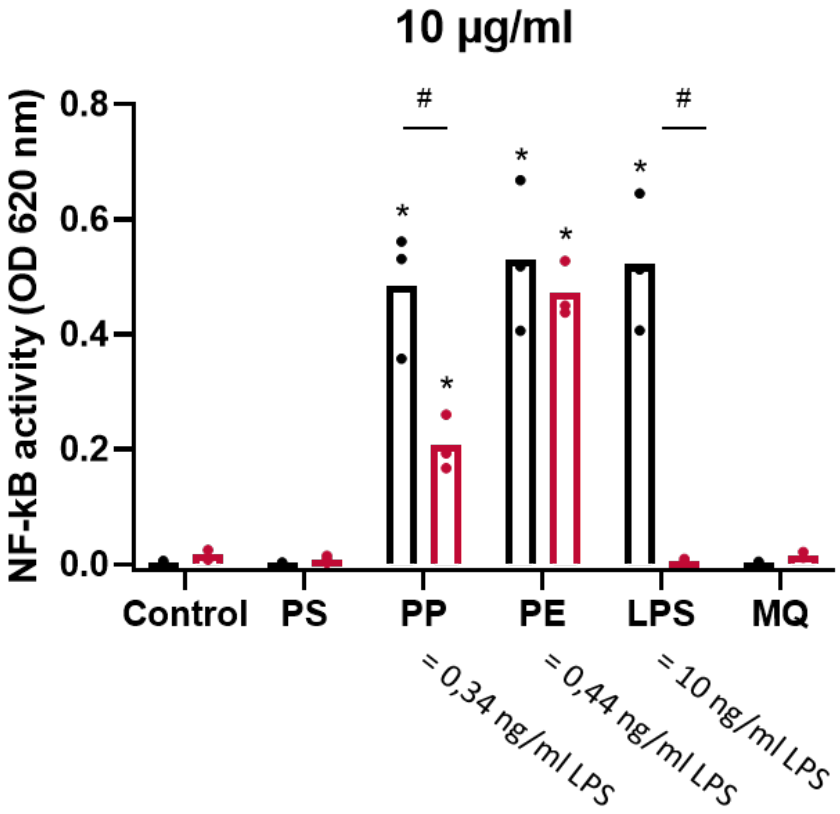
Effects of aged nano-PE and nano-PP on NF-κB expression by dTHP1-macrophages

Table 1. Atomic fraction for elemental composition and C1s fitting obtained by XPS.

	C1s (atom%)				Total C (atom%)	Total O (atom%)	Further atoms	O/C
	C-C, C-H	C-O	C=O	O-C=O				
nanoPE	59.3	19.7	11.2	9.9	55.8	30.9	N, Na, S, Ca, Cl, Au	0.55
nanoPP	87.9	12.0	-	0.1	84.3	11.4	Si	0.14



Effects of aged nano-PE and nano-PP on NF-κB expression by THP1-macrophages



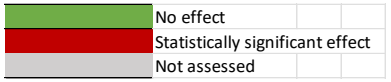
Similar effects on cytokine production: TNF, IL-6, IL-1β

Estimation of LPS content based on LAL assay

	Polymer in stock (µg/ml)	LPS in stock (ng/ml)	Exposed polymer concentration (µg/ml)	Exposed LPS concentration (ng/ml)
PP	41	1,404	10	0,34
PE	82	3,598	10	0,44

van den Berg AET, et al. unpublished.

Effects on dTHP1 macrophages/DCs



		Lysosomal activity			Relative metabolic activity			Membrane integrity			Nf-Kb activity			Cytokine secretion (IL-1b, IL-6, TNF-a)			Uptake								
exposure time (h)		24			24			24			24			24			0.25			3			24		
Concentration (ug/ml)		1	10	100	1	10	100	1	10	100	1	10	100	1	10	100	1	10	100	1	10	100	1	10	100
PS	PS_0.05																								
	PS_0.2																								
	PS_1																								
	PS_NH2_0.2																								
	PS_COOH_0.2																								
MOMENTUM																									
PVC	PVC_<1																								
	PVC_1-5																								
PP	PP/Talc_<1																								
	PP/Talc_1-5																								
PA	PA_1-5																								
TiO2	TiO2																								
verhicle	1-propanol																								
BAM																									
PP	PP																								
PE	PE																								
PET	PET_<10																								
Vehicle	BSA 0.025%																								
	Sterile H2O																								
RIVM																									
PET	PET_PM0.1																								
HDPE	HDPE_PM0.1																								
	HDPE_PM0.1-2.5																								

POLYRISK's Real World Scenarios

External/internal exposure
Immune function effects

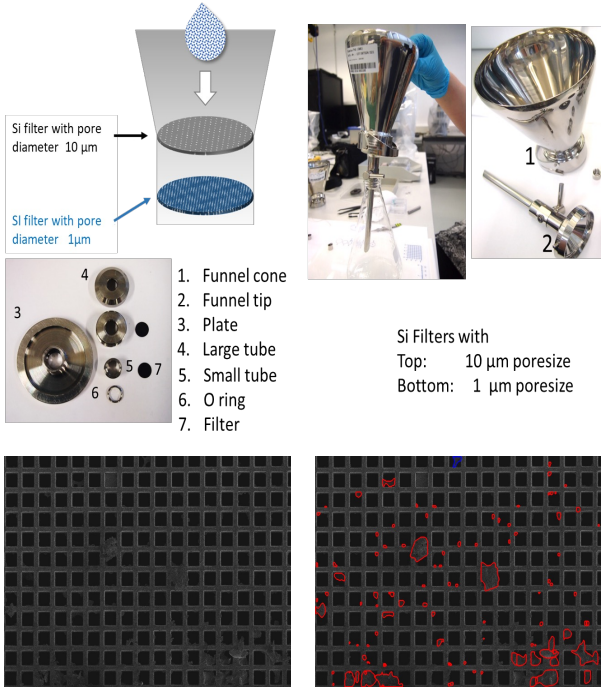
Urban and rural outdoor air ambient MNP

Textile fibre workplace exposure

Indoor Soccer Players exposure to rubber granulate-MNP

MNP in bottled drinking water

MNP in bottled drinking water from Norway: too low levels detected to justify a human study



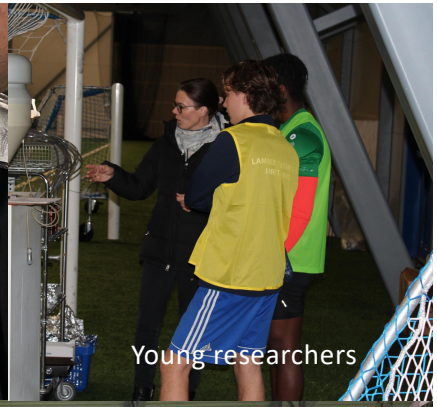
Sample ID	Estimated N of particles (SEM)	N of particles µ-Raman	N of plastic particles/5L
MilliQ (ref.)	589 525	687	1
Normal	576 814	3091	8
Biltema	647 719	1658	25
Telemark Bonaqua	3 336 864	1722	38
Isklar	611 793	682	25
Olden	1 547 975	783	39
Taffel	516 167	1184	59
Imsdal	3 443 056	1013	48
Jula	1 238 380	914	23

POLYRISK's Real World Scenarios

External/internal exposure
Immune function effects

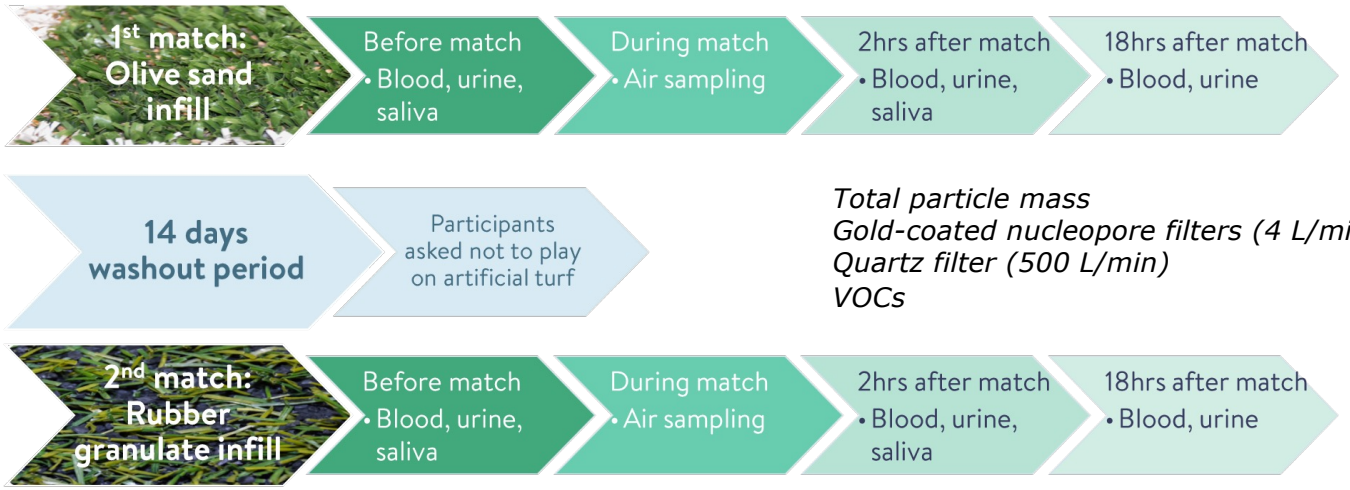
Indoor Soccer Players exposure to rubber granulate-MNP

Indoor soccer hall


Young researchers


Pre-labelling of some 1000 tubes, bottles and vacutainers

Study design-Soccer study



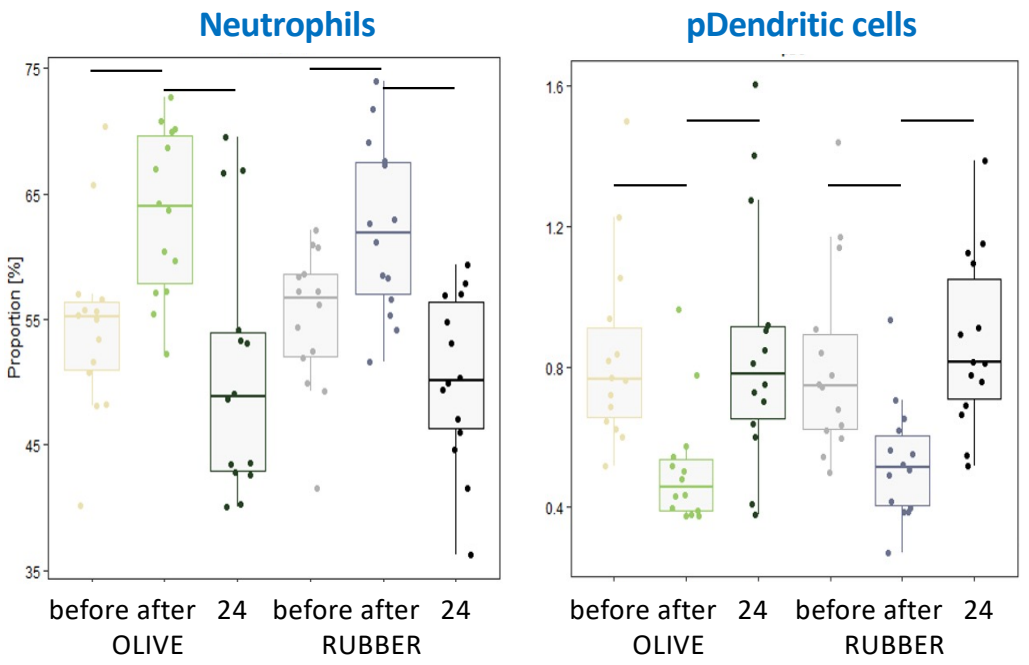
Total particle mass
Gold-coated nucleopore filters (4 L/min)
Quartz filter (500 L/min)
VOCs

Healthy adolescents		**36**
Sex (male)	N (%)	25 (69)
BMI	Mean (SD)	22.5 (2.6)
Played on artificial turf last 4 days		
Match 1	N (%)	5 (13.9)
Match 2	N (%)	5 (13.9)

Biological samples	**Analyses**
Plasma (6 time points)	Cytokine profiling
	Chemicals
	Metabolomics
	miRNA
Whole blood (6 time points)	MNP
	Immune cell profiles
	DNA methylation
24h Urine (4 time points)	Chemicals
Saliva (4 time points)	Cytokine profiling

Air samples and Effects on Blood Leukocytes

Olive sand	Crumb rubber
Total number of particles	
22 000/m^3	6 500/m^3
Background (eg, soot, biological)	
54%	60%
MNP	
5%	16%
Black tyre rubber	
5%	10%
Olive stone	
12%	0%
Fungal spores	
8%	0%



Football study
Main conclusion regarding particles in the air

Inside and outside of the halls

- No differences for soot, mineral or natural particles
- Black tyre particle in all samples, source likely the outdoor air

Olive sand hall

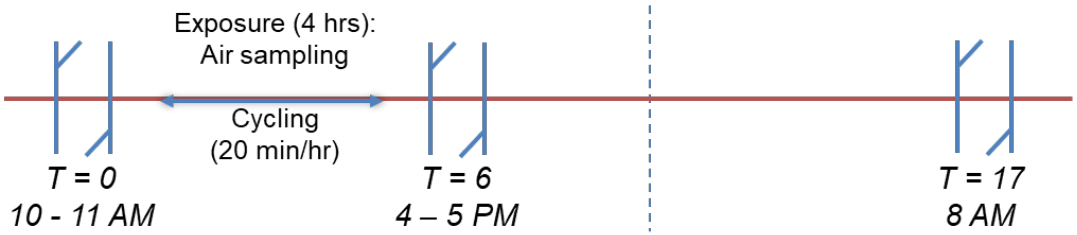
- Mainly olive stones particles, quartz and black tyre particles dectected
- Spores detected (Aspergillis and Penicillium)

Rubber granulate hall

- Mainly black tyre rubber and quartz particles detected
- Large black tyre particles detected, originating from the granulates

Traffic study - design

- Controlled human exposure study
- 23 healthy, non-smoking, young volunteers
- Locations with varying traffic amount and driving style
  - **Stop & Go, Highway, Urban Park**
  - **4 hrs. at location, with 20 min/hr. cycling**
- Measurements done in
  - 2022 (August – October)
  - 2023 (May – July)



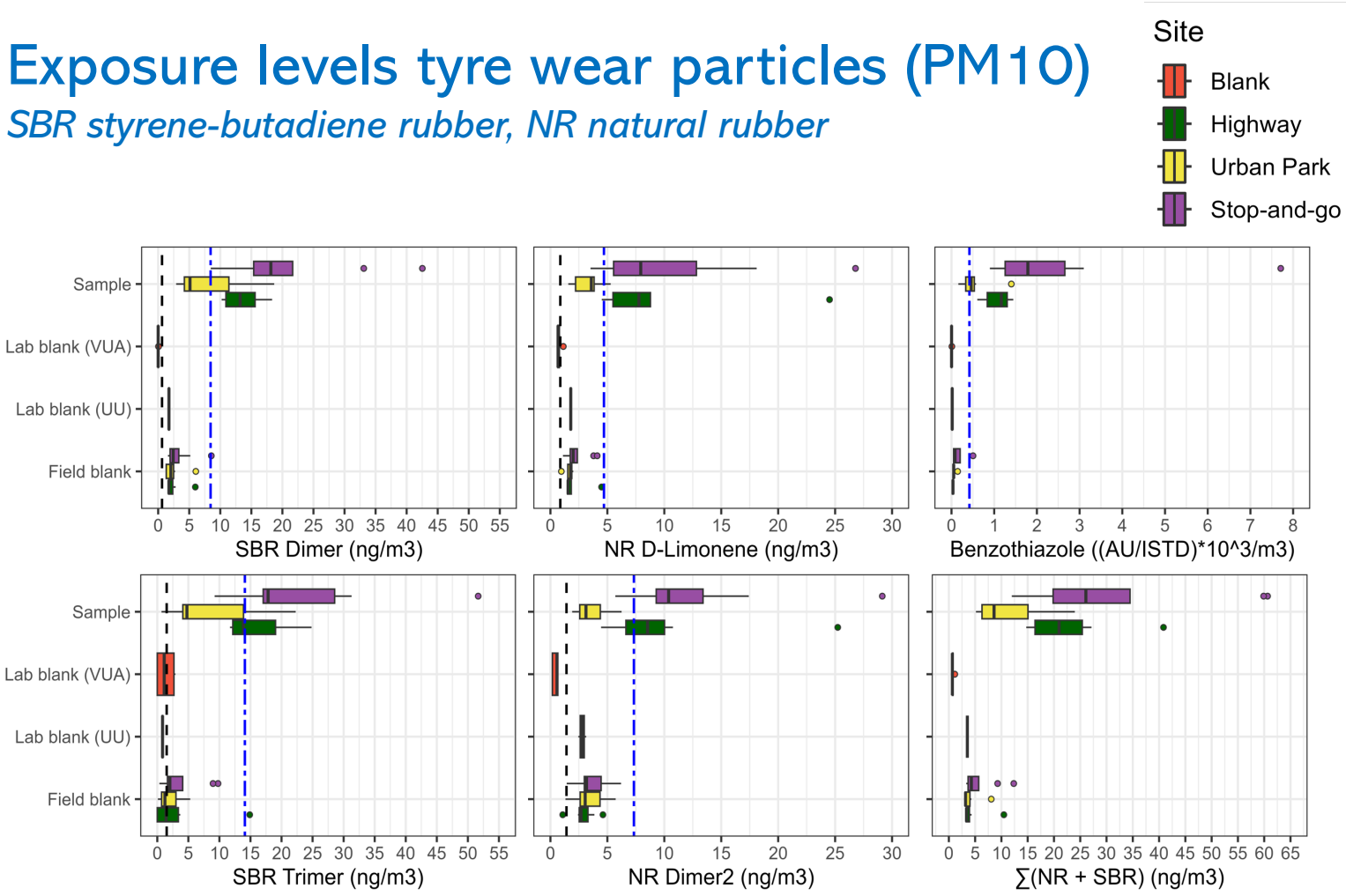
Stop & go location

Lookout-point highway

Urban city park

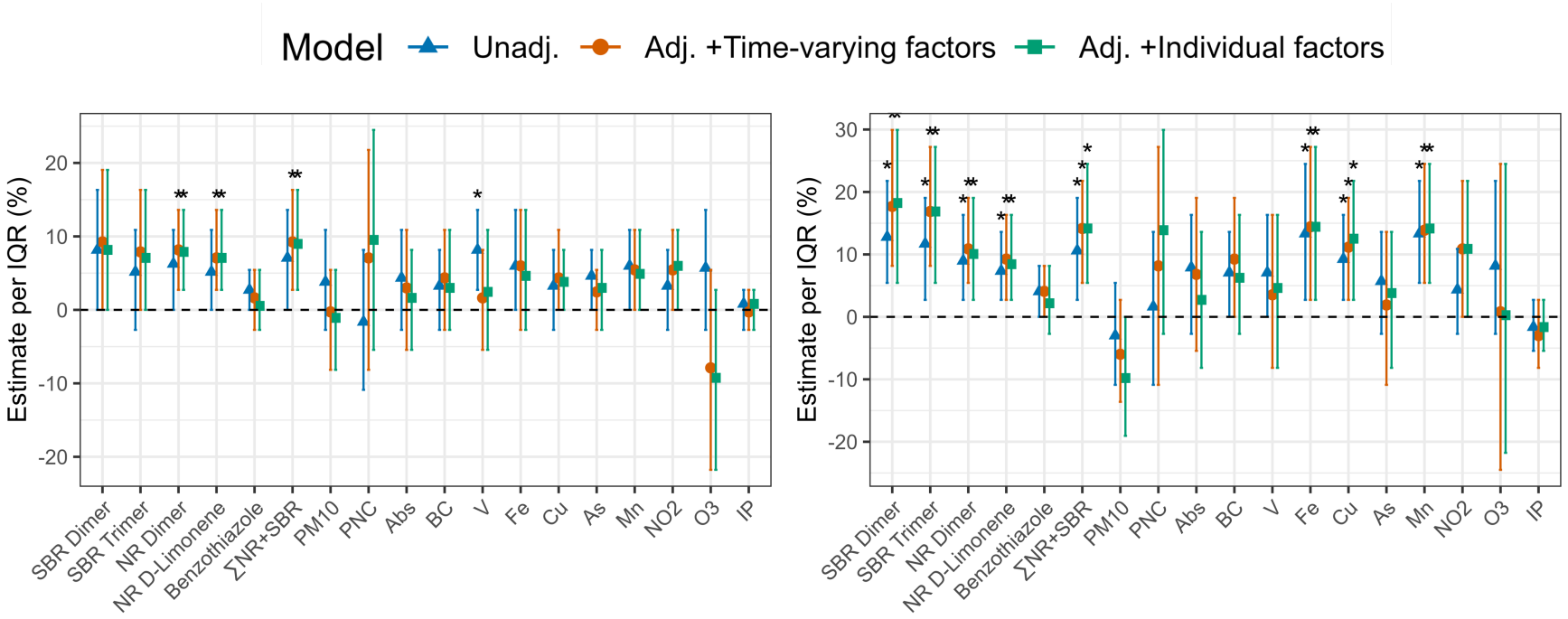
Exposure levels tyre wear particles (PM10)

SBR styrene-butadiene rubber, NR natural rubber



Traffic study: levels of monocytes in blood

6hr and 17 hrs after start of study



Percentage change in white blood cell subset per interquartile range of atmospheric pollutant levels, measured immediately after exposure (t = 6 hrs, left side), and following morning (t = 17 hrs, right side), versus baseline.

Summary of health-related immunological effects

↑ plasma monocytes **(7.1 ; 9.3%*)**	↑ plasma monocytes **(9.3 ; 17.7%*)** ↑ WBCs, granulocytes (neutrophils **7.4 ; 14%*)**	Mostly driven by traffic-related MNPs.
↑ plasma EGF, MMP1, IL7 (5.2 ; 16.9%)	↓ plasma IL18*, CXCL9* **(-5.2 ; -8,4%)** ↑ plasma EGF (4 ; 18.9%)	
Cell markers	↓ CD11b, CD10 on granulocytes (-8.8 ; -13.5%) ↓ CD16* on granulocytes **(-2.8 ; -5.2%*)** ↓ CD11b on monocytes **(-20.7 ; -25.5%*)**	Driven by BC, Abs and/or brake-wear related trace metals
Lung function / Respiratory symptoms	No effects	

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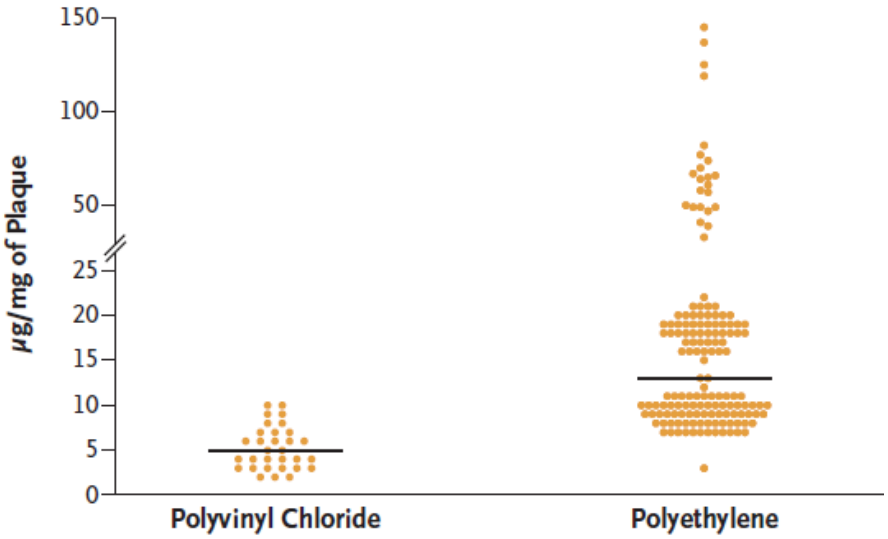

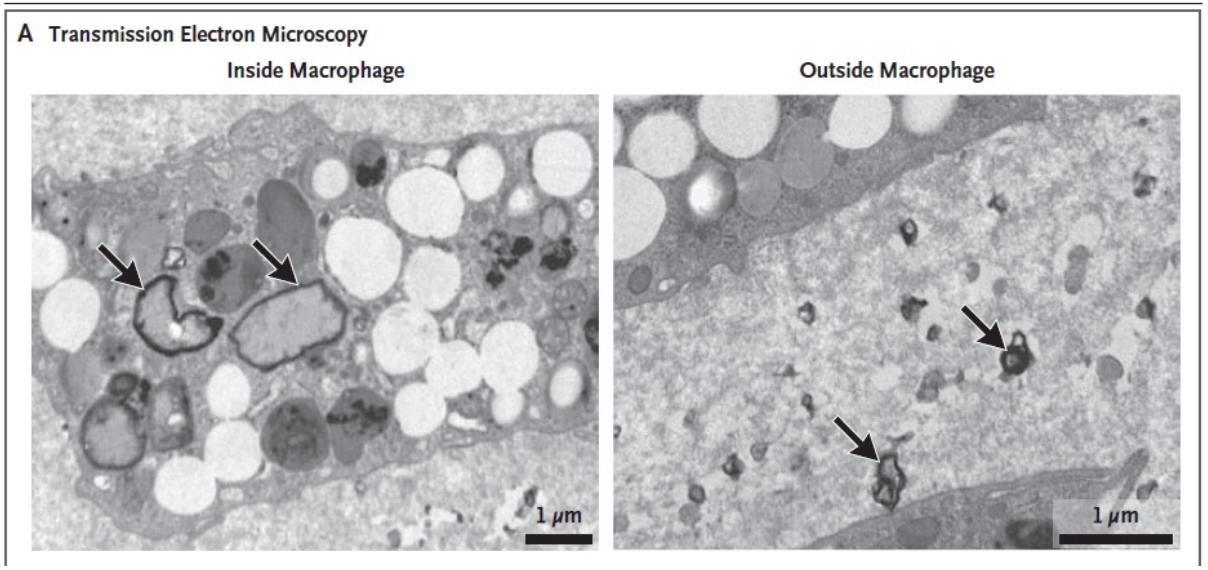

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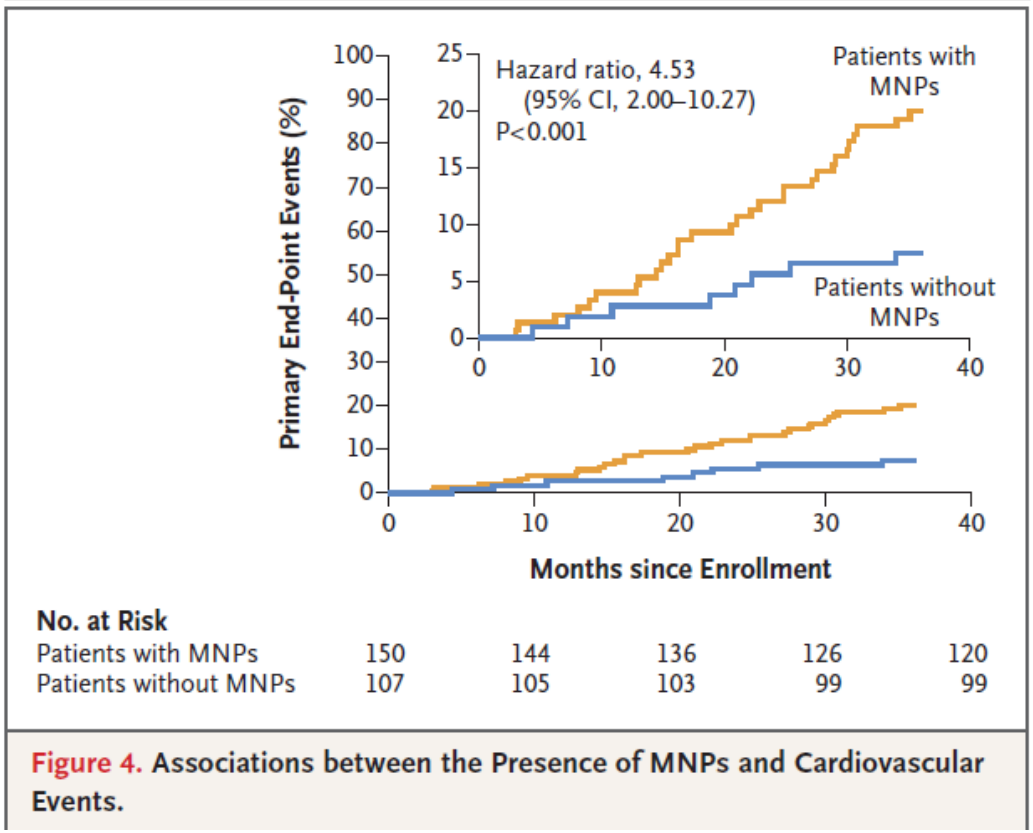
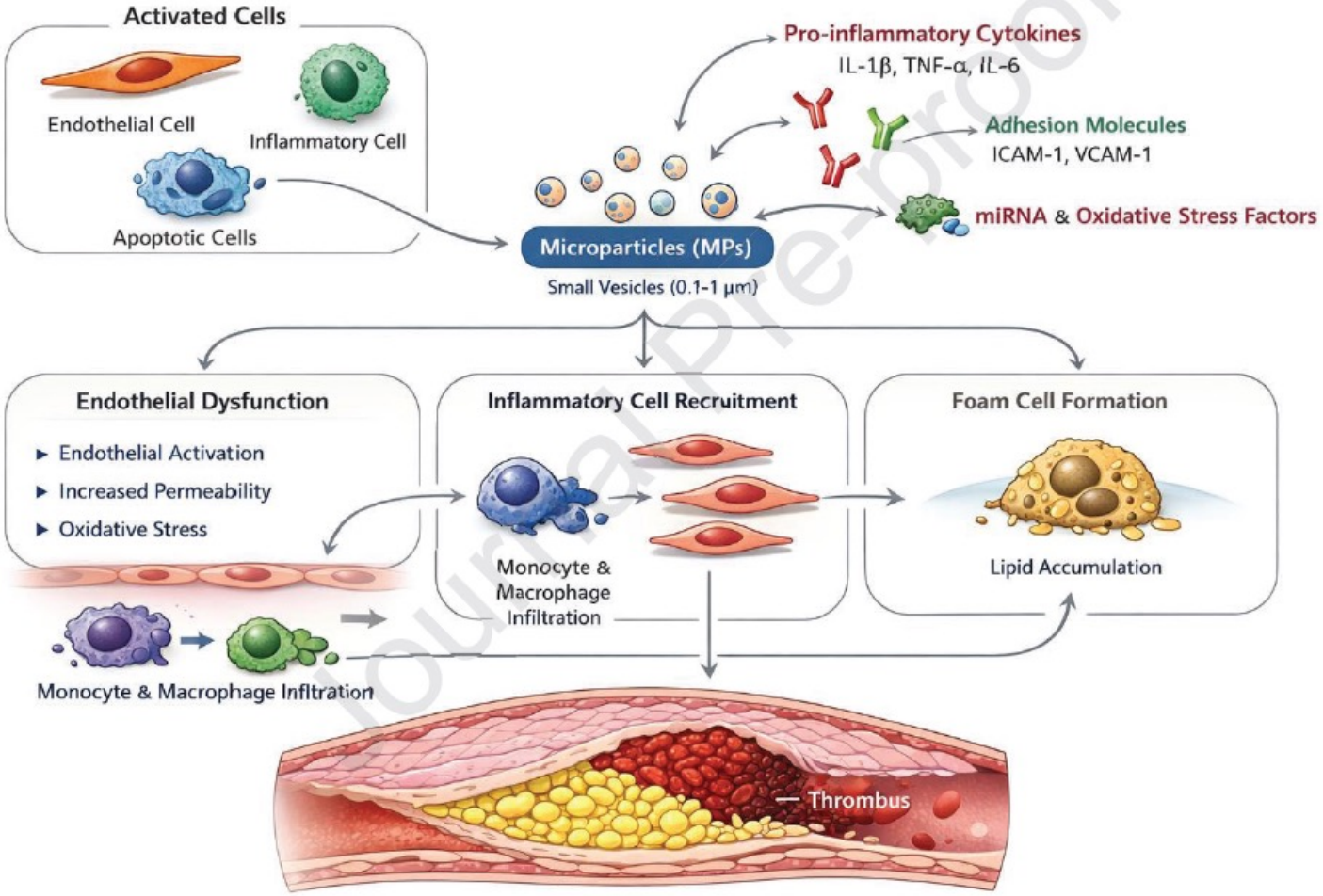


Figure 4. Associations between the Presence of MNPs and Cardiovascular Events.



Atherosclerotic Plaque Progression

Please cite this article as: Gu E, Devorkin B, Chu M, Emerging Links Between Cardiovascular Disease and Microplastics Exposure – A Narrative Review, *Hellenic Journal of Cardiology* (2026), doi: https://doi.org/10.1016/j.hjc.2026.02.007.

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The Guardian

‘A bombshell’: doubt cast on discovery of microplastics throughout human body

Exclusive: Some scientists say many detections are most likely error, with one high-profile study called a ‘joke’

There is no doubt about the ubiquity of plastic pollution in the natural world, but some scientists are dubious about the health damage said to be caused by microplastics in the human body.

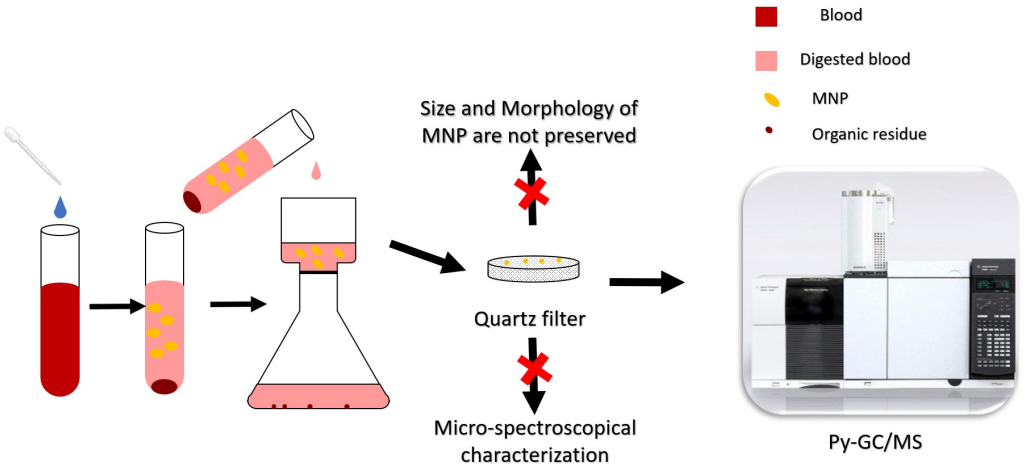
Sampling and analytical method development

Protocols for:

1) blood analysis
2) analysis of air samples
3) liquid sample filtration

(using different types of filtration)

***Figure**: Digestion and filtration protocol for blood analysis.*
Based on:
Leslie et al., Environment International, 163, 2022, 107199.



Full length article

Environment International 163 (2022) 107199

Discovery and quantification of plastic particle pollution in human blood

Heather A. Leslie [a], Martin J.M. van Velzen [a], Sicco H. Brandsma [a], A. Dick Vethaak [a,b], Juan J. Garcia-Vallejo [c], Marja H. Lamoree [a,*]

[a] *Dept. of Environment and Health, Faculty of Science, Vrije Universiteit Amsterdam, De Boelelaan 1108, 1081 HZ Amsterdam, the Netherlands*
[b] *Deltares, Delft, the Netherlands*
[c] *Cancer Center Amsterdam and Amsterdam Infection and Immunity, Amsterdam University Medical Center (VUmc location), De Boelelaan 1108, 1081 HZ Amsterdam, the Netherlands*

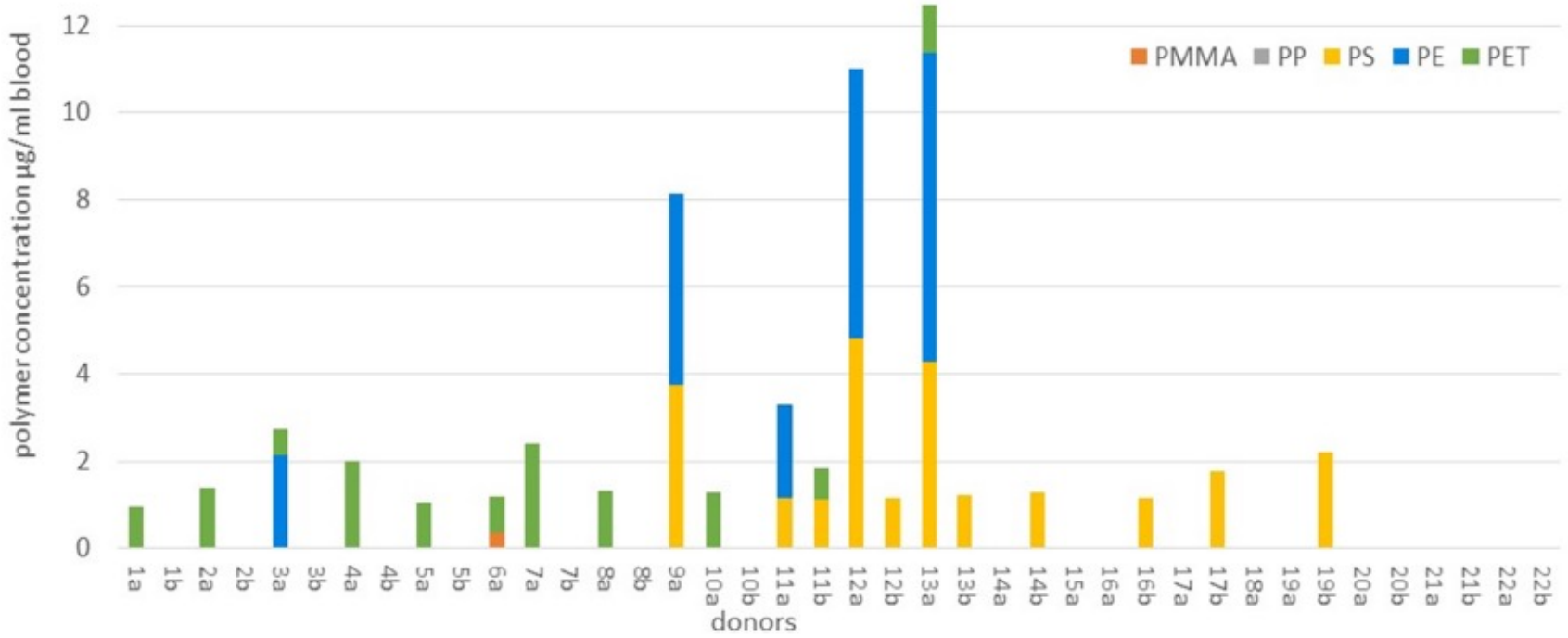


Table 2 Summary of the limit of detection (LOD) and limit of quantitation (LOQ) and recoveries (%) obtained for the quality control samples ($n = 15$) along with the respective relative standard deviation (%RSD)

				QC recoveries (batch analysis) ($n = 15$)
Polymer	**Quantitation compound**	**LOD (ng/mL)**	**LOQ (ng/mL)**	**Percentage recovery (%RSD)**
PMMA	methyl methacrylate	49	163	82 (19)
PP	2,4-dimethyl-1-heptene	14	48	57 (14)
PS	5-hexene-1,3,5-triyltribenzene	52	175	102 (44)
PE	1-eicosene	245	817	86 (30)
PVC	1,2-dihydronaphthalene	120	401	82 (28)
PET	benzoic acid	79	265	91 (28)

Nardella *et al. Microplastics and Nanoplastics* (2025) 5:48
https://doi.org/10.1186/s43591-025-00152-7

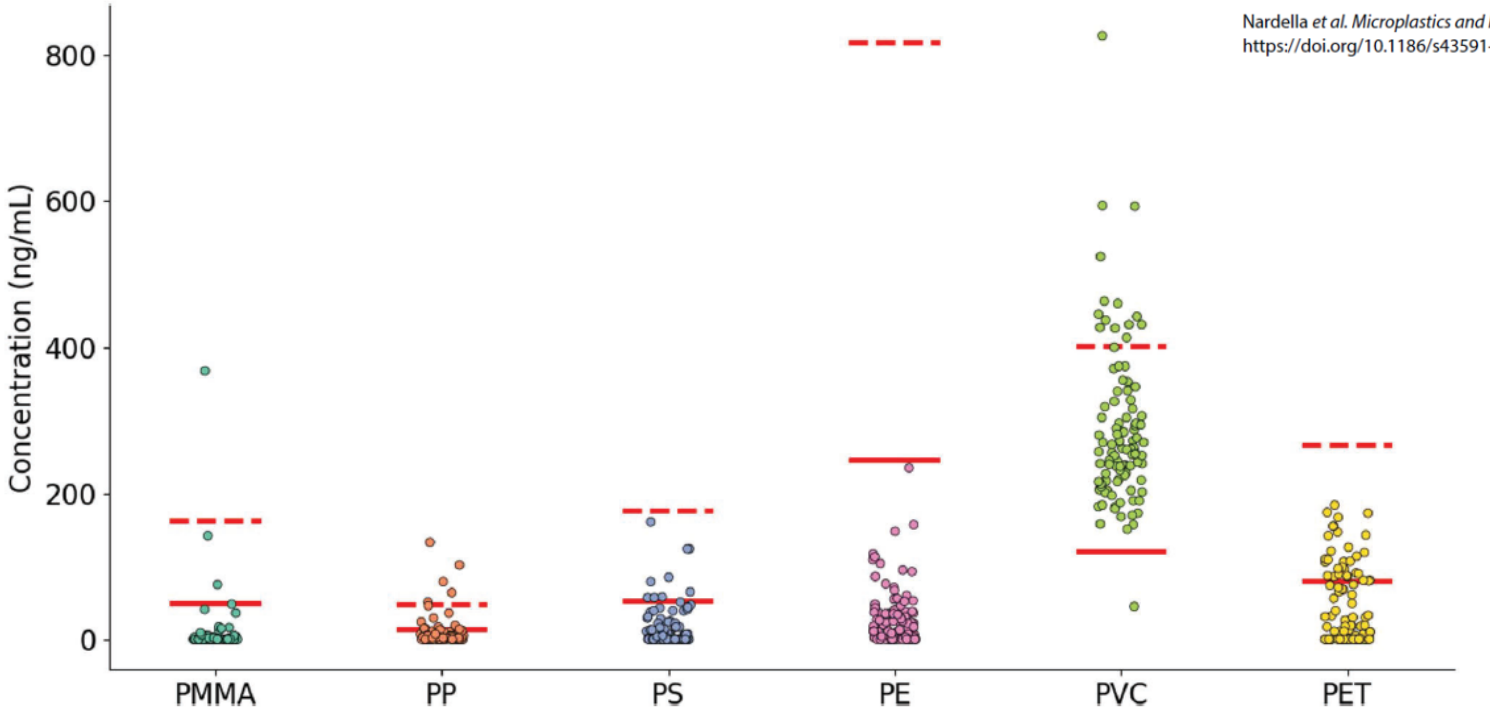


Fig. 2 Concentration in ng/mL for PMMA, PP, PS, PE, PVC and PET in blood samples. The red solid lines denote the limit of detection (LOD), while the red dashed lines indicate the limit of quantification (LOQ) for each analyte. The concentrations for each polymer were blank-corrected

Rauert *et al. J Environ Expo Assess* 2022;1:13
DOI: 10.20517/jeea.2022.04

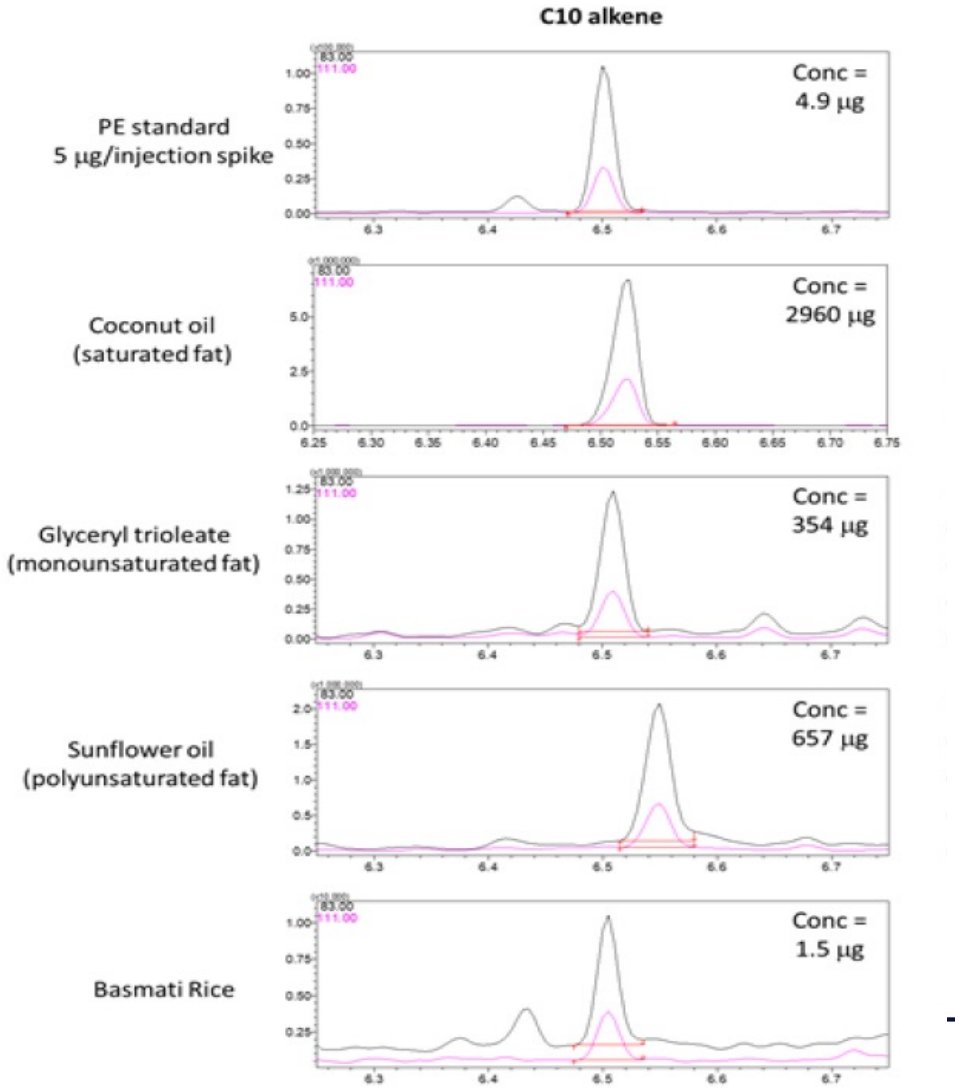
Journal of Environmental Exposure Assessment

Research Article

Open Access

Extraction and Pyrolysis-GC-MS analysis of polyethylene in samples with medium to high lipid content

Cassandra Rauert[1,2], Yufei Pan[1], Elvis D. Okoffo[1], Jake W. O'Brien[1], Kevin V. Thomas[1,2]



Summing up-conclusions

- Micro- and nanoplastics (MNPs) are a huge and complex challenge for hazard, exposure and risk assessment.

- Health effects (i.e. pro-inflammatory effects by MNPs) depends on their size, shape and surface chemistry (influenced by weathering/aging)

- Leachates, all chemicals coming from plastics

- Currently, we cannot assess the human health risk, because appropriate exposure and hazard data are lacking.
  - Exposure (incl sample collection and prep) methods urgently need standardization
  - Kinetics/body distribution of MNPs
  - Exposure source mapping (where/how do MNP arise?)

- How to mitigate (washing machines, tyre handling)?

Polyrisk is part of the European Cluster on
Health Impacts of Micro- and NanoPlastic, CUSP.

This project has received funding from the European Union's Horizon 2020
research and innovation programme under grant agreement No 964766.

polyrisk.science

Thank you for your attention.