国家海洋环境监测中心
NATIONAL MARINE ENVIRONMENTAL MONITORING CENTER

The Alteration of Toxicity in Marine Organisms by Micro and Nanoplastics, Co-existing with Typical Organic Chemicals

Speaker: Prof./Dr. Ying WANG/王 莹 (wangying@nmemc.org.cn),

Organization: National Marine Environmental Monitoring Center (NMEMC),

Ministry of Ecology and Environment (MEE), China

生态环境部 国家海洋环境监测中心

Date: 30 October, 2014

National Marine Environmental Monitoring Center (NMEMC)
国家海洋环境监测中心

Location of Dalian

Xinghaiwan bridge, Dalian, Liaoning
星海湾大桥，大连，辽宁

Introduction

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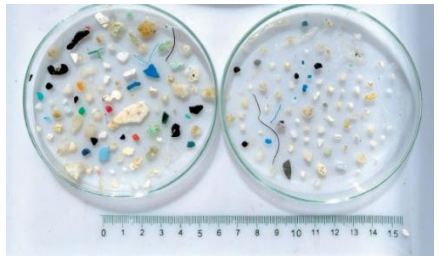
Microplastics and Nanoplastics (MNPs) in the marine environments

Size

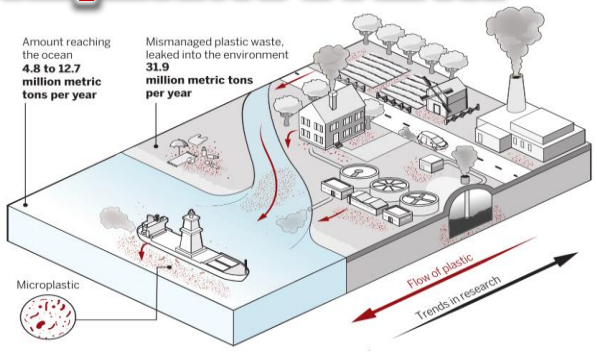


- Microplastics: 1 μm ~ 5 mm
- Nanoplastics: < 1 μm

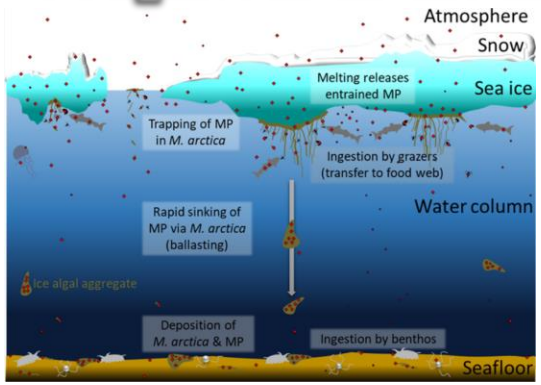
Specific characteristics

- Small size
- High bioavailability
- Potential ecological risks

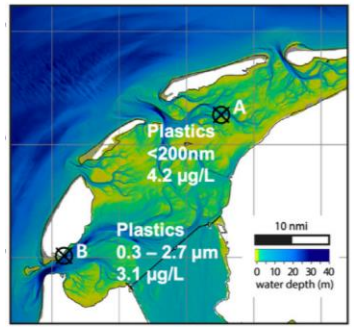
Complicated Sources



Ubiquitous in the Marine Environments



- MNPs in the Wadden Sea
- Polymers: PET, PS



Environ. Sci. Technol. 2022, 56, 15, 10818-10828; Sci Total Environ, 2022, 846:157371.
Biol Lett 2017, *Environ. Sci. Technol.* 2023, 57, 6799-6807; *Environ. Sci. Technol.* 2017, 51, 13689−13697.

Introduction

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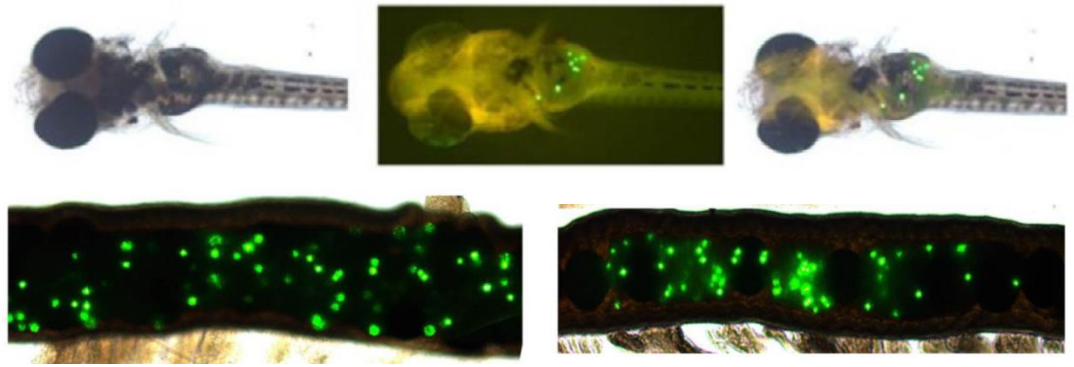
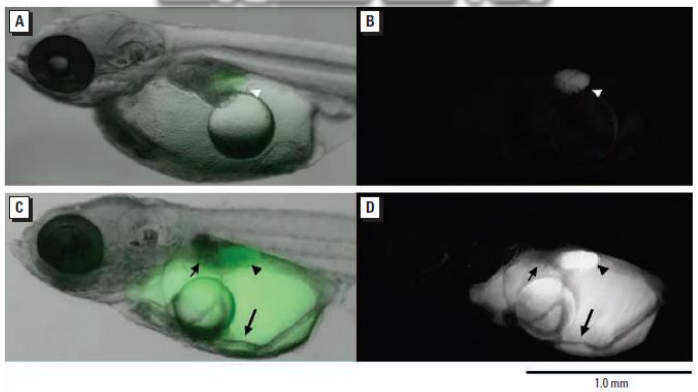
Uptake by Aquatic Organisms and Adverse Effects of MNPs

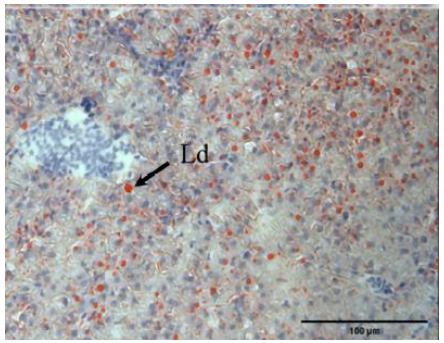
MPs: Accumulation in intestine of marine medaka adults

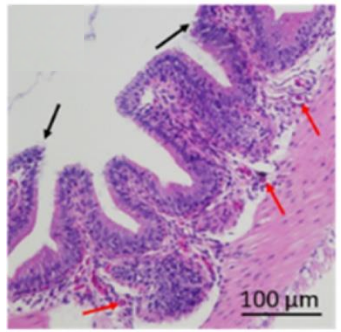


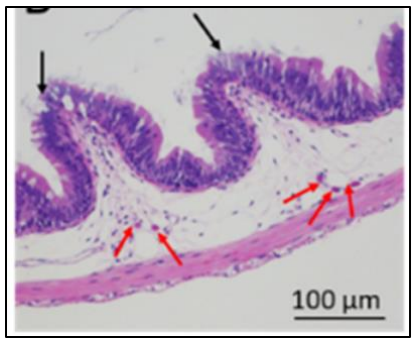
NPs: Accumulation in yolk of medaka larvae



Oxidative stress, inflammation and histopathological alterations







Chemosphere, 2019. 228: 93-100. Environ Health Perspect, 2006. 114: 1697-702.
Environ. Sci. Technol. 2023, 57, 2804-2812. *Environ Health Perspect*, 2023. 131:. 47006.

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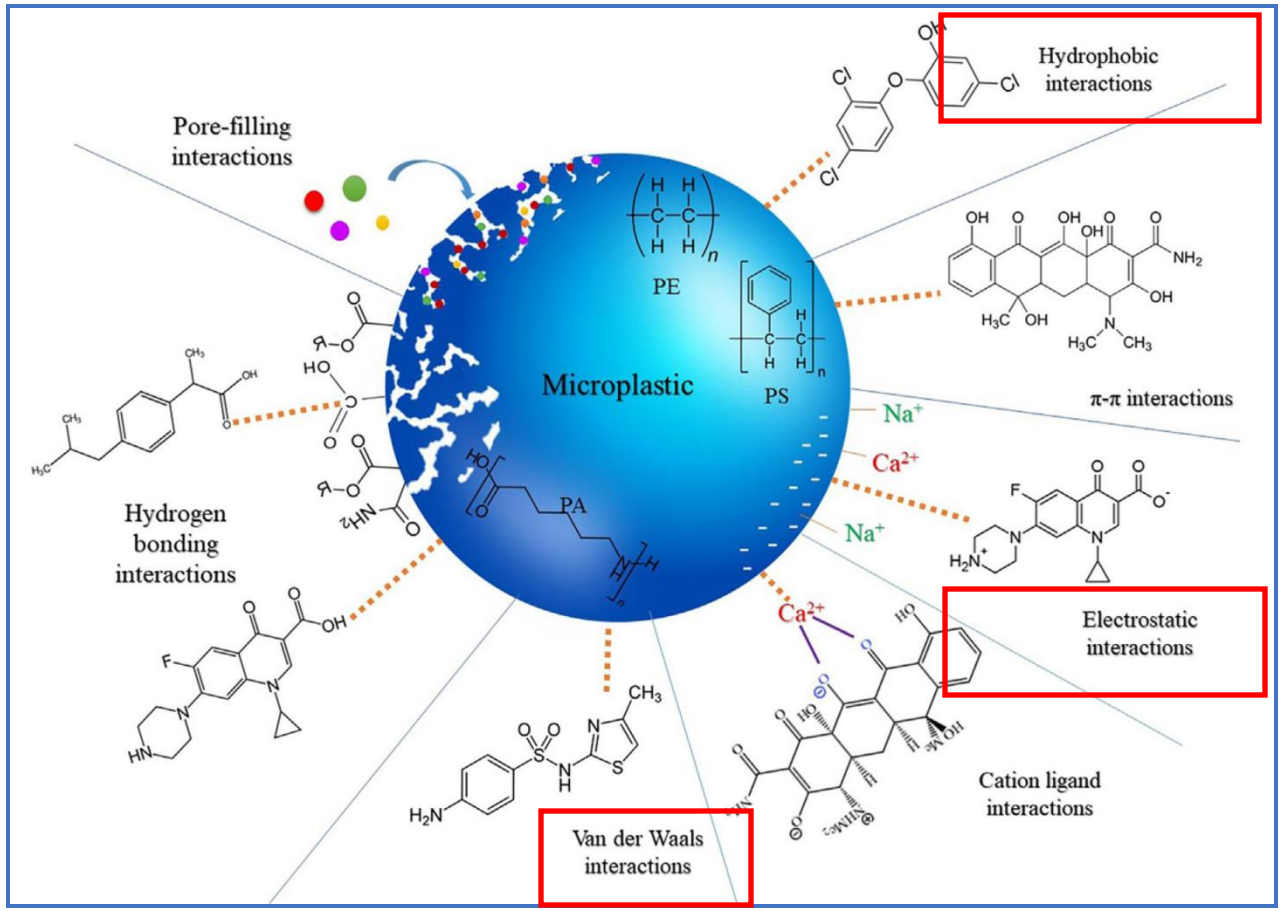
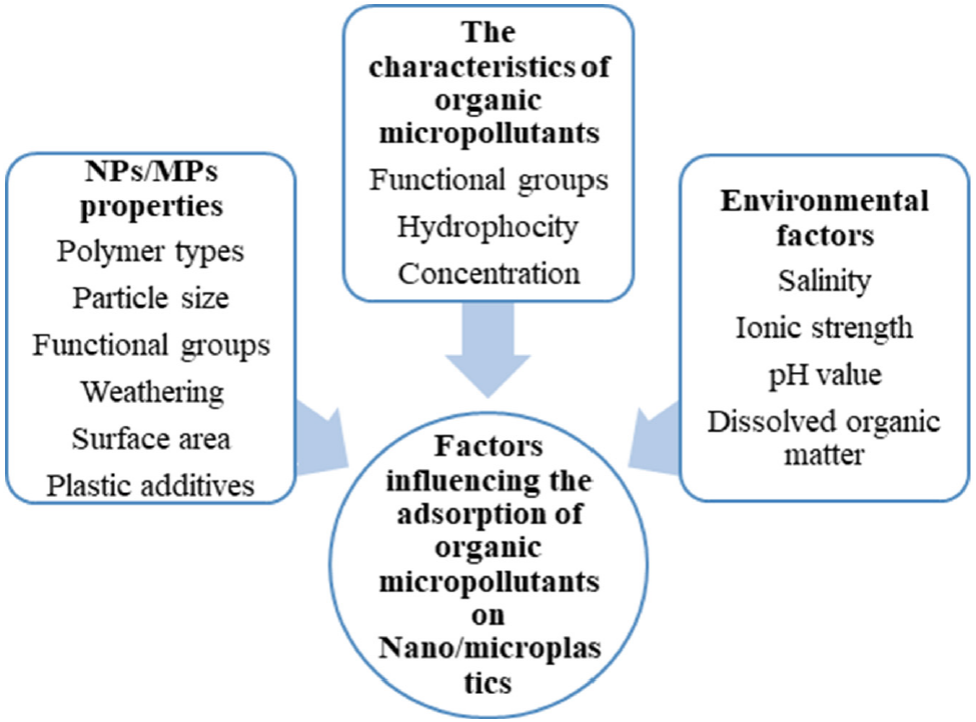
Interaction of organic micropollutants with MNPs





Sci Total Environ, 2021, 797: 149140. Environ. Int. 2021, 149, 106367

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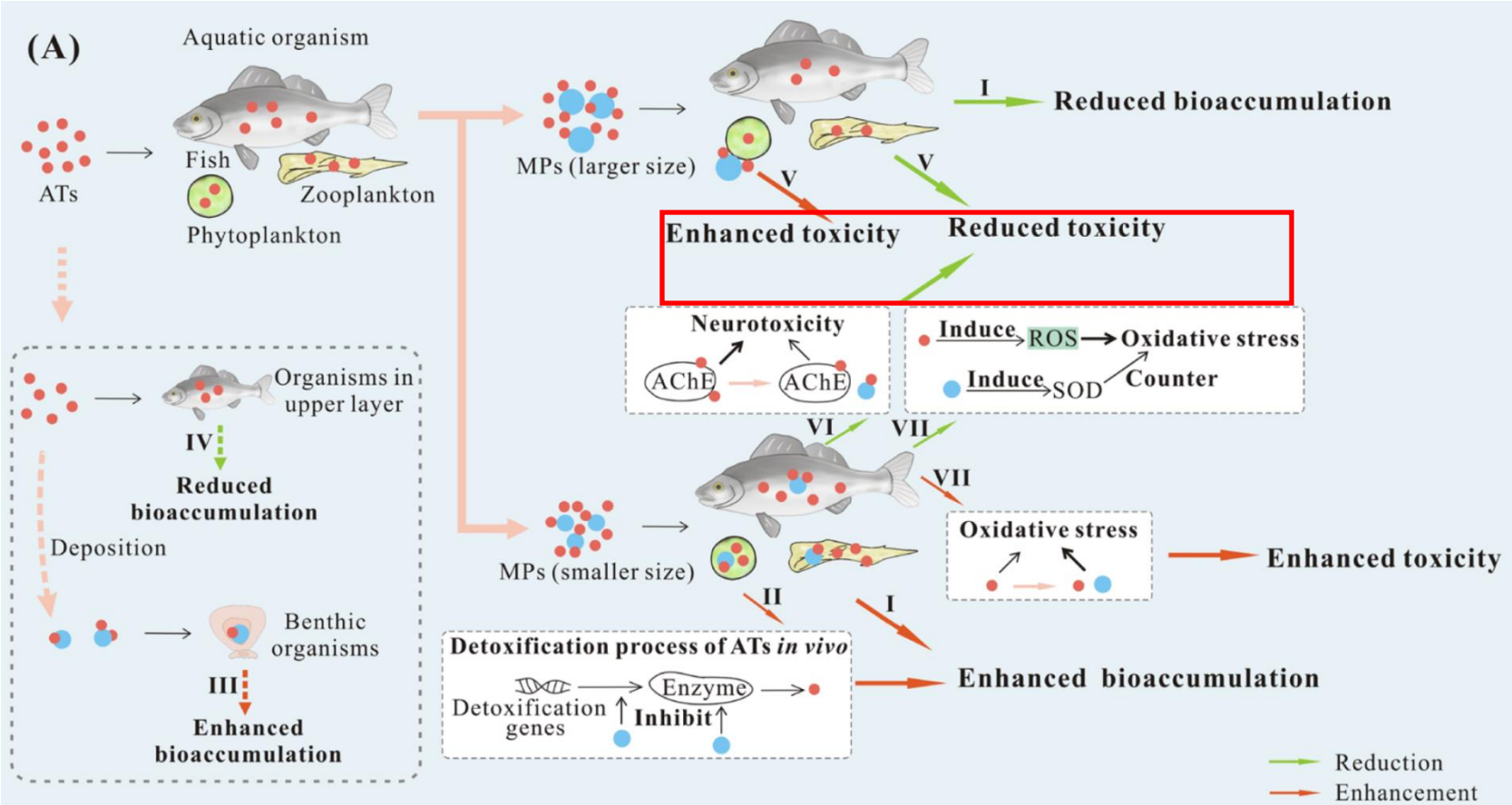
Toxicity alteration of individual MNPs or Organic Chemicals



primarily due to changes in their bioavailable concentrations

Environ Sci Technol, 2021, 55(23): 15579-15595.

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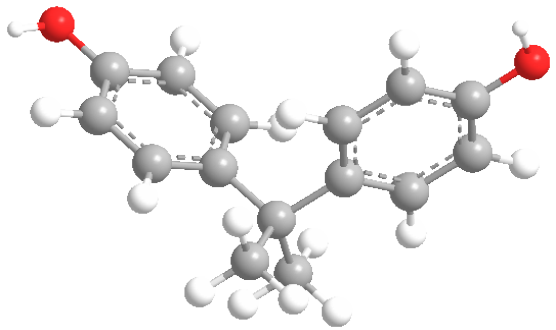
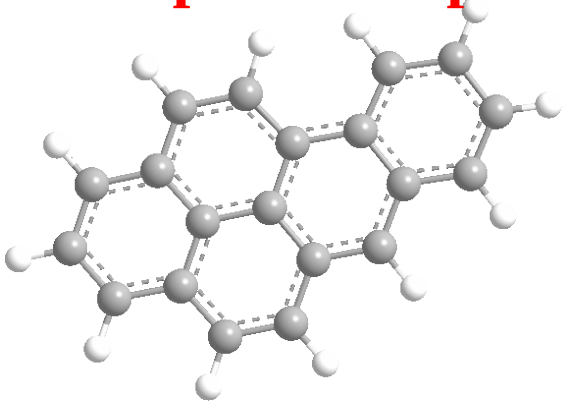
Knowledge gaps remain regarding the toxicity alterations and underlying mechanisms of MNPs coexisting with polar or non-polar chemicals.

- **polar compound**



Bisphenol A (BPA), a typical EDC

- **non-polar compound**



Benzo[a]pyrene (B[a]P), a typical five-ring PAH

- **First, which compounds will govern the overall toxicity of the mixture at environmentally relevant concentrations?**
- **Second, how will the bioavailability and toxicity of each chemical be altered after their interaction?**

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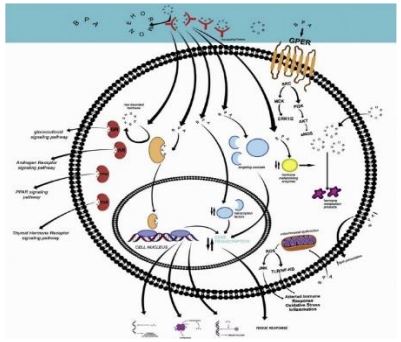
➢ Case 1

Contents lists available at ScienceDirect
Chemosphere
journal homepage: www.elsevier.com/locate/chemosphere

Bisphenol A decreases the developmental toxicity and histopathological alterations caused by polystyrene nanoplastics in developing marine medaka *Oryzias melastigma*

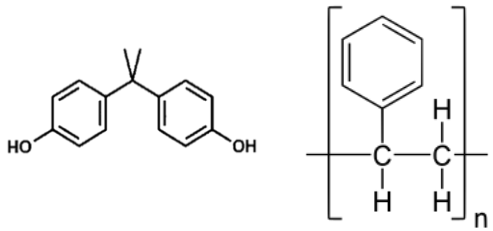
Fuwei Yu [a,b], Fei Jin [b], Yi Cong [b], Yadi Lou [b], Zhaochuan Li [b], Ruijing Li [b], Baojun Ding [a,**], Ying Wang [b,*], Jingwen Chen [c], Juying Wang [b]



- hypothalamic-pituitary-gonadal-liver axis
- growth, development and reproduction

Molecular mechanism **Adverse effects**

Arch Environ Contam Toxicol, 2019, 76, 246-254.
Reprod Toxicol, 2008, 25 (2): 177-183.



BPA + PS-NPs

Toxicity ?

Experimental Design

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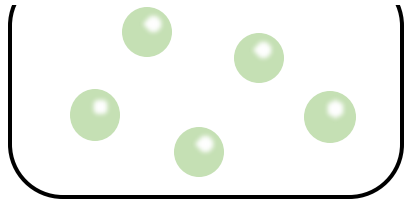
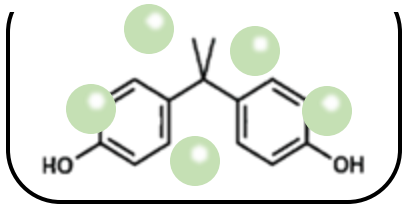
50 nm PS-NPs (55 μg/L)



Dutch Wadden Sea
< 200 nm 4.2 μg/L
(Materic, et al., 2022)

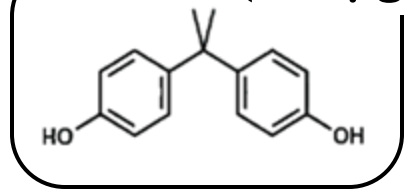
BPA + PS-NPs)



Oryzias melastigma

6 hpf → **21 dpf**

BPA (100 μg/L)



Turkish Seas, 15 μg/L
(Ozhan and Kocaman, 2019)

Toxicity at individual level for early life stages

hatching, survival, body length, deformities

Histopathological alterations

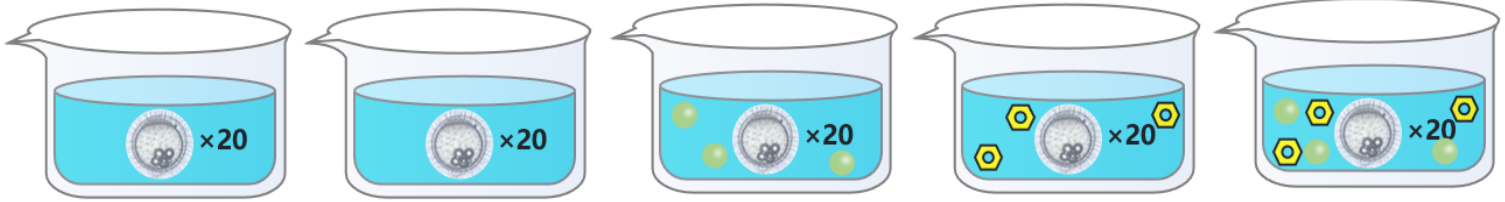
liver and heart of larvae

Transcriptomic analysis by RNA-seq

analyzing DEGs and key pathways involved

Interaction of NPs and BPA

Accumulated nanoplastics in larvae



Adverse Effects on Medaka

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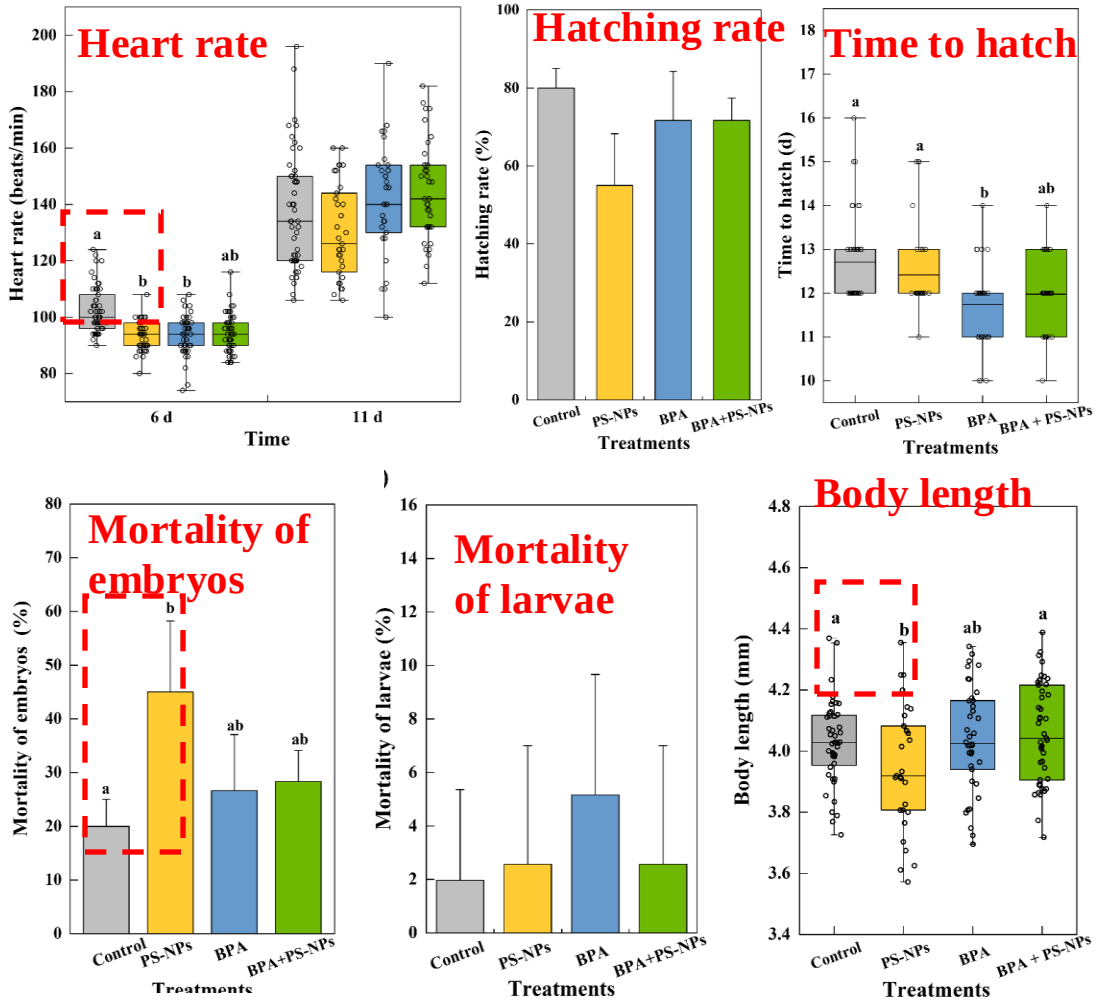
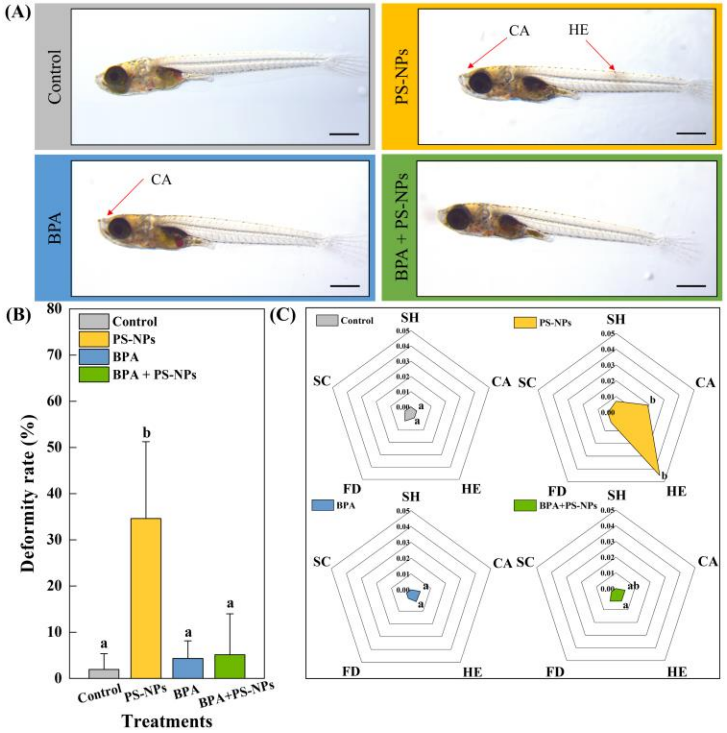
Individual: hatching, survival and deformities





PS-NPs: decreased embryonic heart rate, and embryonic survival and larval body length; larval deformities such as hemorrhaging and craniofacial abnormalities.

Control PS-NPs BPA BPA + PS MPs

Yu et al., 2023, ***Chemosphere***, *336: 139174.*

Adverse Effects on Medaka

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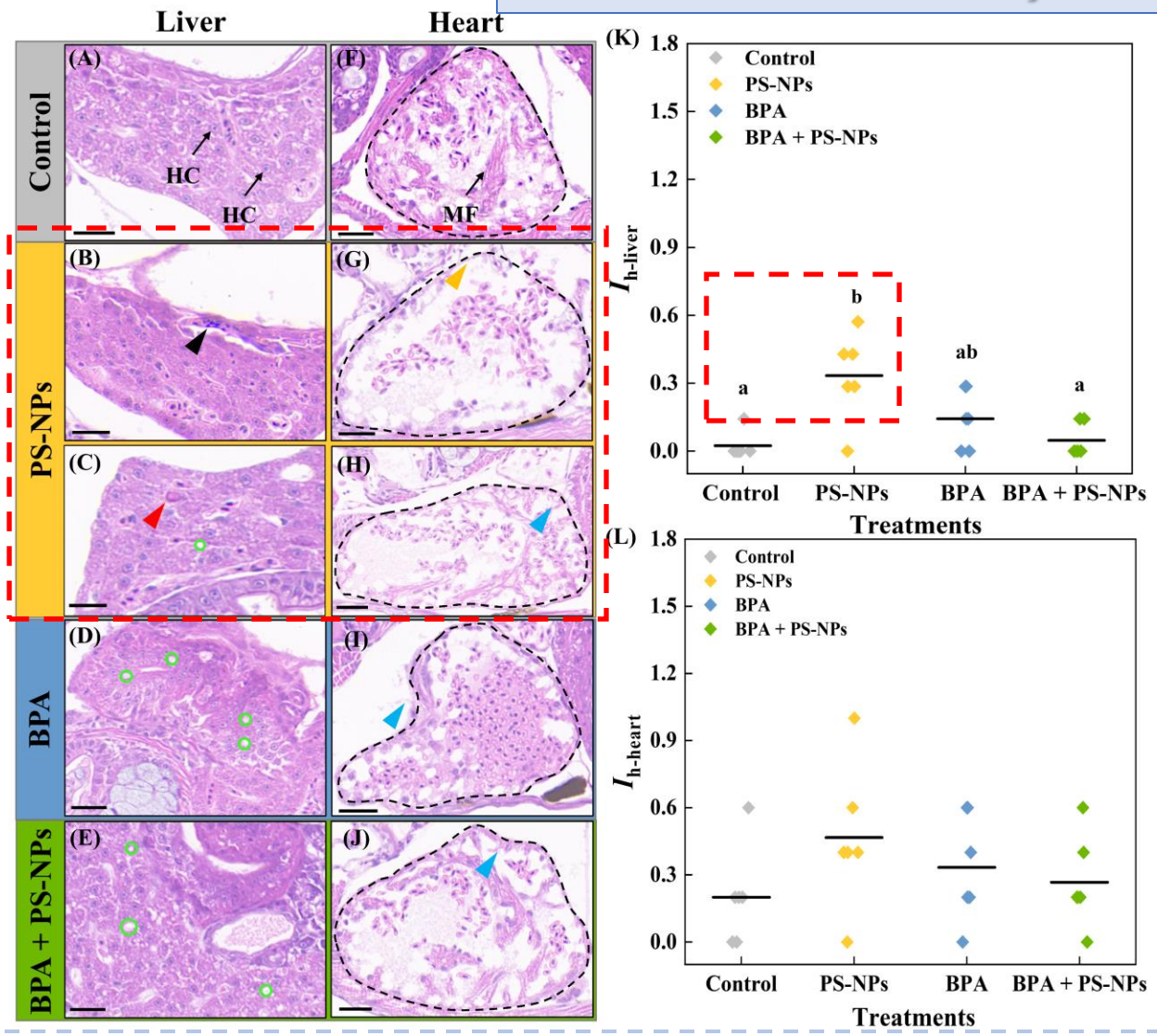
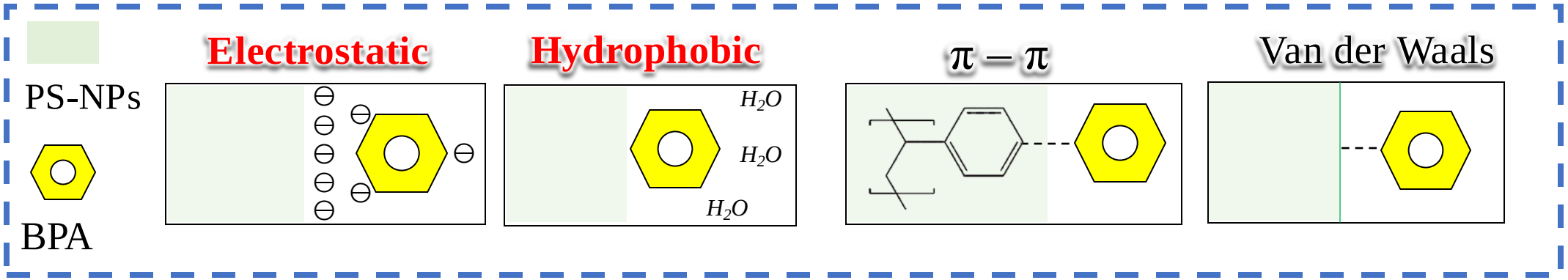
Tissue: larval liver, heart



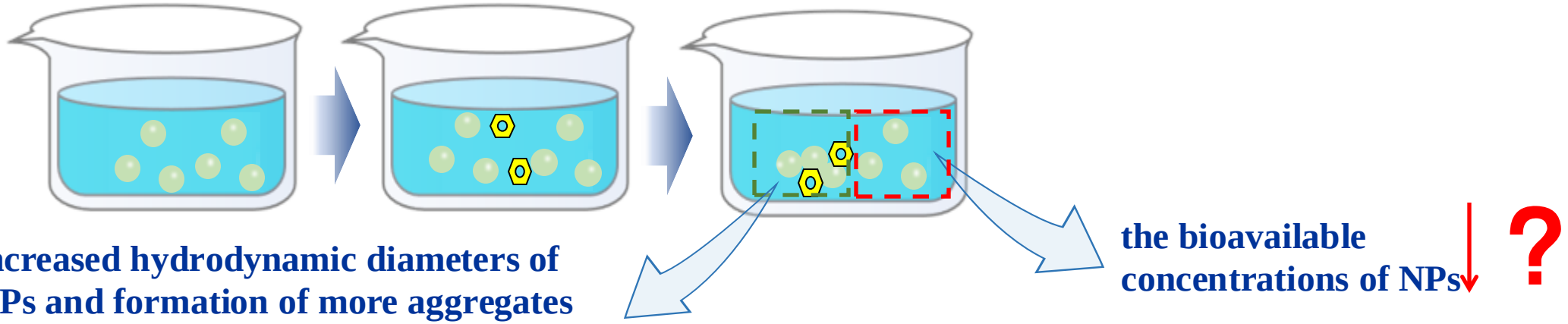
PS-NPs:
Liver: early inflammatory responses (vacuolation, apoptosis and necrosis)
Heart: a thinner myocardial wall, reduced myocardial fiber and irregularity in cardiac morphology

Yu et al., 2023, ***Chemosphere***, *336: 139174.*

The Interaction Between PS-NPs and BPA



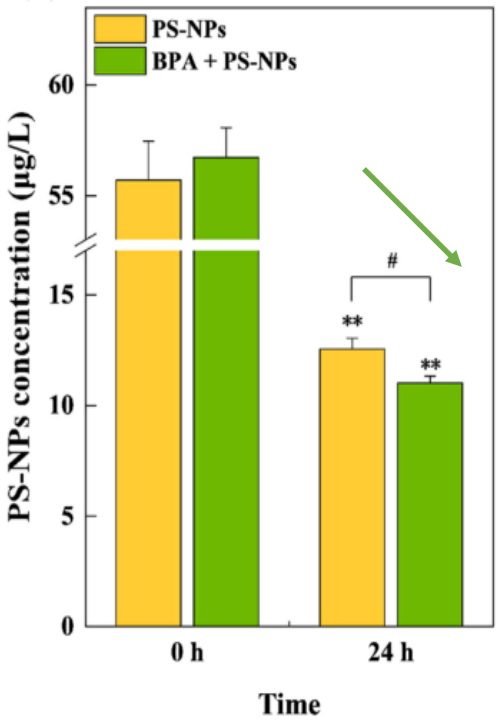
- **The sorption of BPA onto the surface of PS-NPs is primarily driven by electrostatic and hydrophobic interactions.**

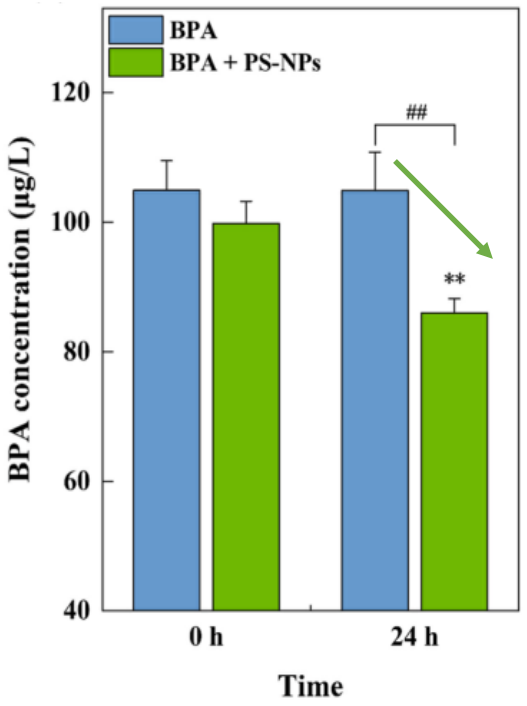


increased hydrodynamic diameters of NPs and formation of more aggregates

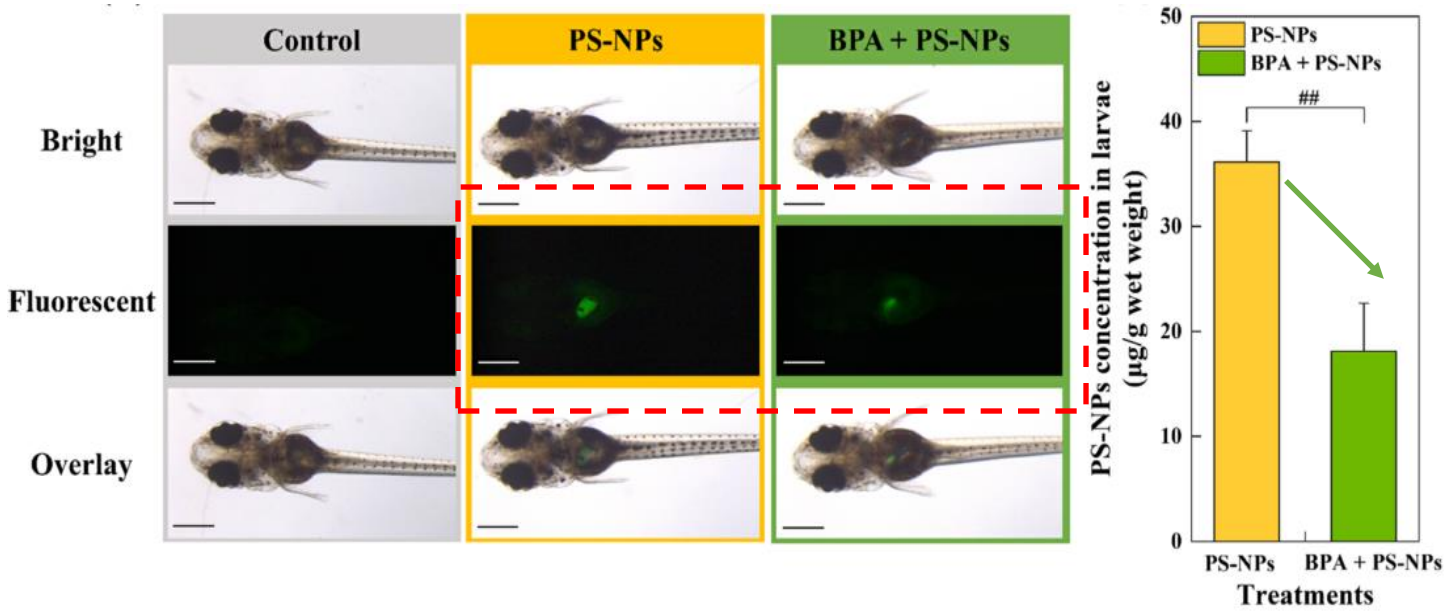
the bioavailable concentrations of NPs ↓ ?

Effects of BPA on the Bioaccumulation of PS-NPs





The waterborne concentrations of PS-NPs and BPA



Bioaccumulation of PS-NPs in marine medaka larvae

The bioaccumulation of PS-NPs by medaka larvae was reduced in the presence of BPA. » **BPA mitigated the toxic effects of PS-NPs**

Molecular Mechanism

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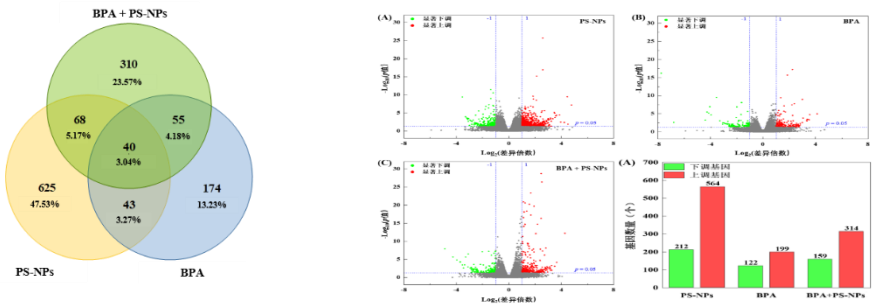
Toxicity mechanism at the molecular level

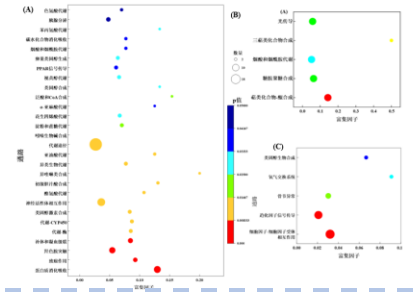
unpublished data

DEGs



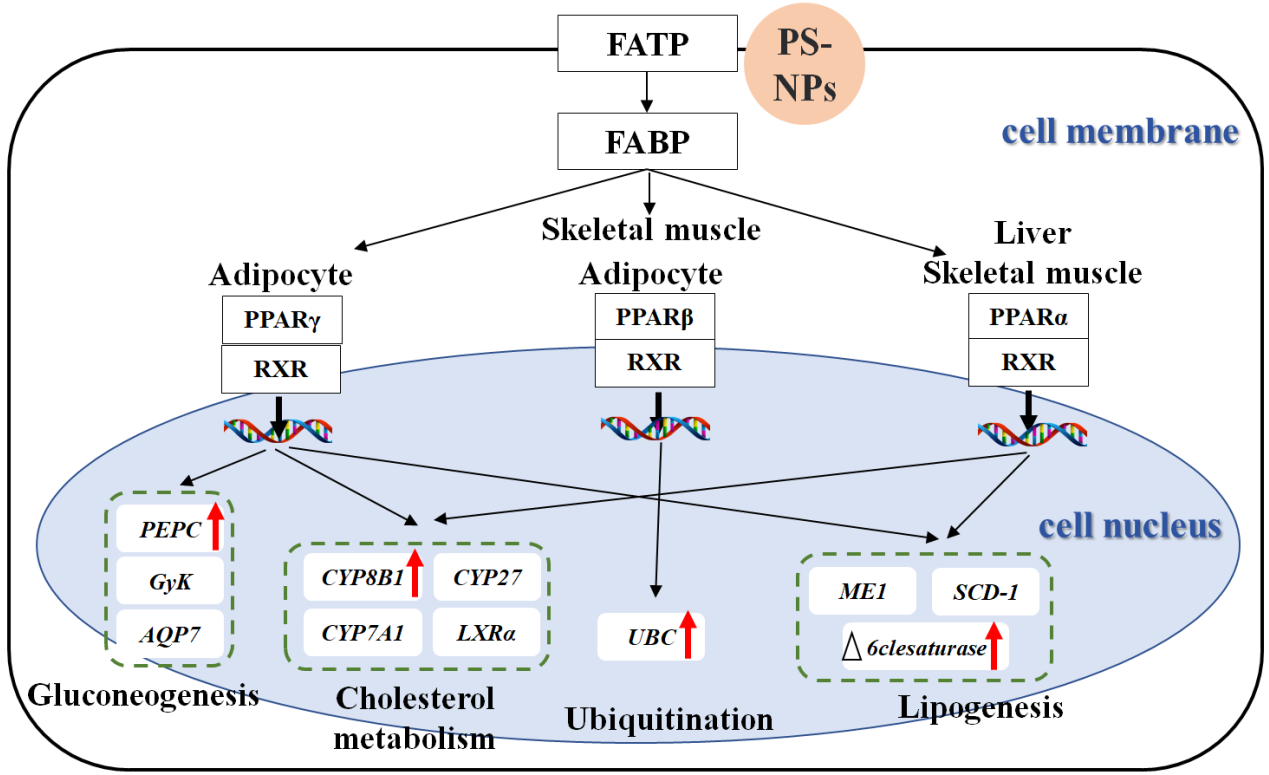
Function of DEGs is is mainly about development, immune and lipid metabolism

KEGG



Metabolic and Immune pathways

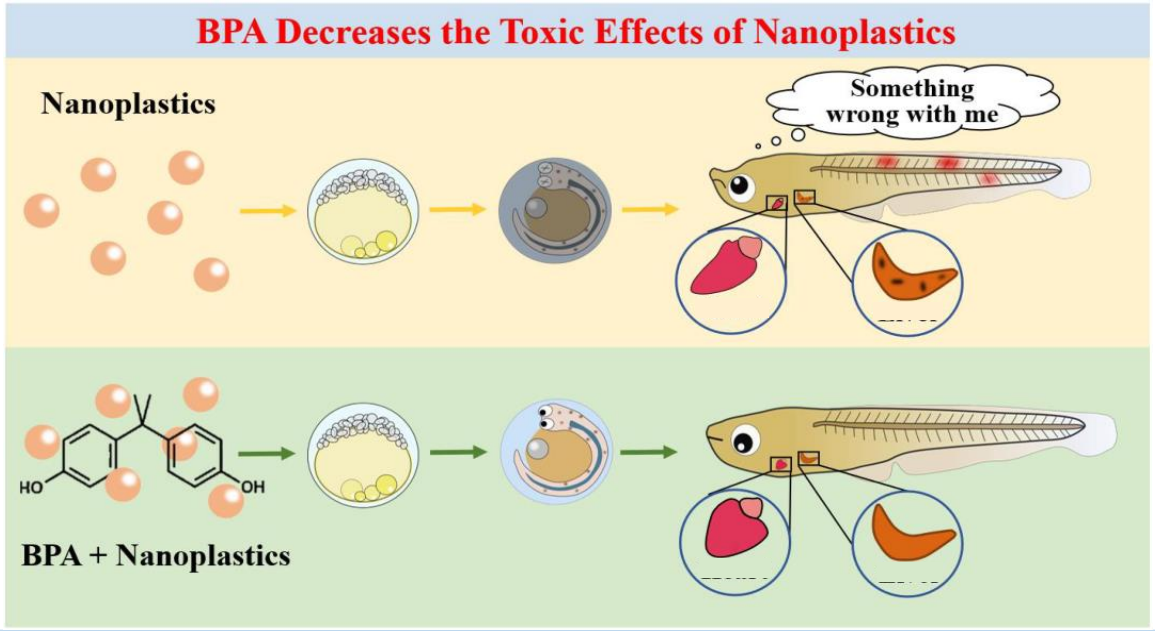
PS-NPs: governed by PPAR pathways

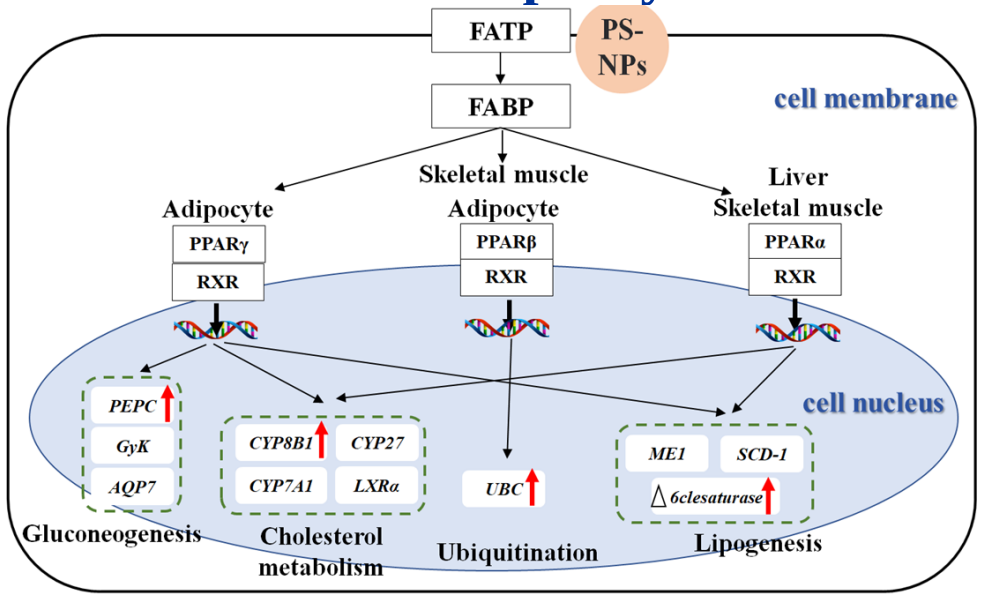


The metabolic and immune pathways were impacted, with the Peroxisome Proliferator-Activated Receptor pathway playing a key role in hepatotoxicity and developmental toxicity.

Summary

- **Single exposure to PS-NPs resulted in embryonic mortality, growth inhibition, developmental deformity and histopathological alterations in the liver.**
- **Co-exposure to PS-NPs and BPA mitigated all of these adverse impacts. This phenomenon may be due to the absorption of BPA by PS-NPs, which subsequently led to a decrease in the bioaccumulation of PS-NPs.**
- **Developmental toxicity in medaka following a single exposure to PS-NPs is primarily regulated by the PPAR pathway, which is involved in cholesterol metabolism and lipid synthesis.**





Introduction

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➢ Case 2

Aquatic Toxicology 256 (2023) 106430

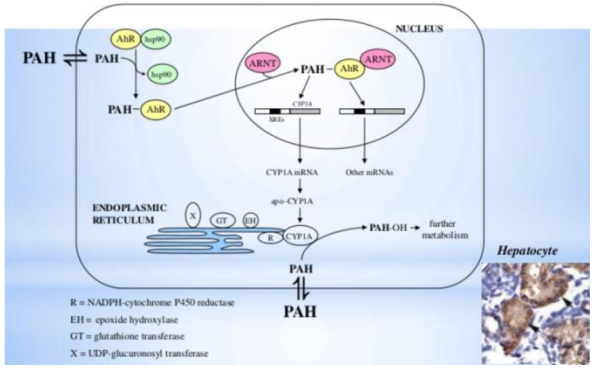
Contents lists available at ScienceDirect

Aquatic Toxicology

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

Polystyrene microplastics alleviate adverse effects of benzo[a]pyrene on tissues and cells of the marine mussel, *Mytilus galloprovincialis*

Ying Wang [a,#,*], Mingxing Zhang [a,#], Guanghui Ding [b], Huahong Shi [c], Yi Cong [a], Zhaochuan Li [a], Juying Wang [a,*]

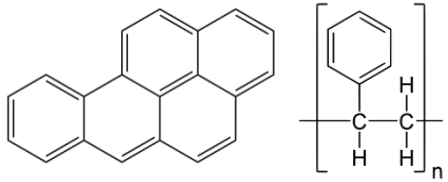


Molecular mechanism

Mar Pollut Bull, 2015, 99:28-34.

- alterations of immunological responses,
- antioxidant system
- onset of genotoxicity

Cellular effects



B[a]P + PS-MPs

Toxicity?

Experimental Design

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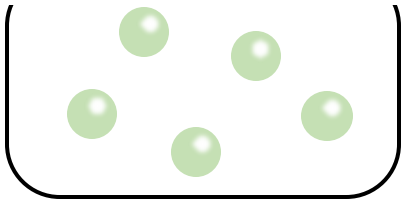
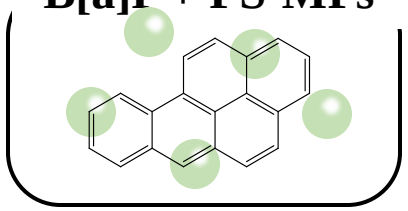
10 μm PS-MPs (5.5 μg/L)



Dutch Wadden Sea
0.3-2.7 μm, 3.1 μg/L
(Materic, et al., 2022)

B[a]P + PS-MPs

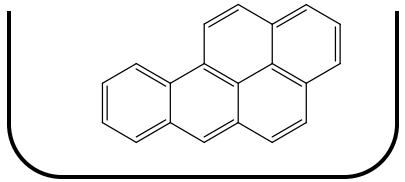


Mytilus galloprovincialis

adults, for 96 h

Gills + Digestive glands

B[a]P (0.1 μg/L)



Liaodong Bay
0.07 μg/L (maximum)
(Wang, et al., 2014)

Histopathology

thinning of filaments, mean epithelial thickness (MET) and circularity of digestive tubules

Oxidative stress

Lveles of SOD and GST in gills and digestive gland, ROS levels in haemolymph

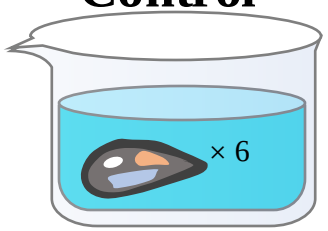
Gene expression by qRT-PCR

stress response, immune, and detoxification

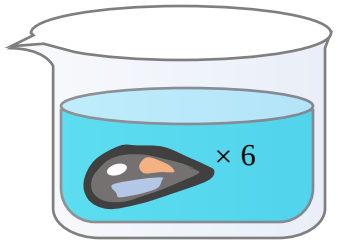
Interaction of MPs and B[a]P

Accumulated microplastics and B[a]P in biota

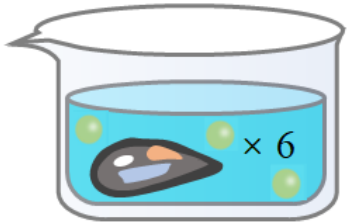
Control



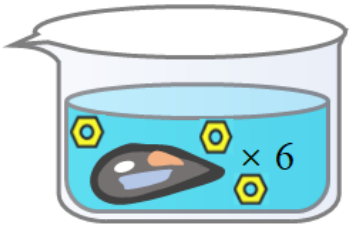
Filtrate



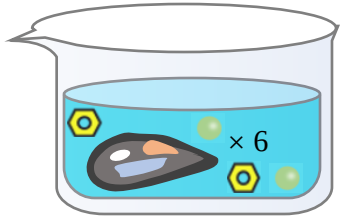
PS-MPs



B[a]P



B[a]P+PS-MPs



Adverse Effects on Tissues and Cells

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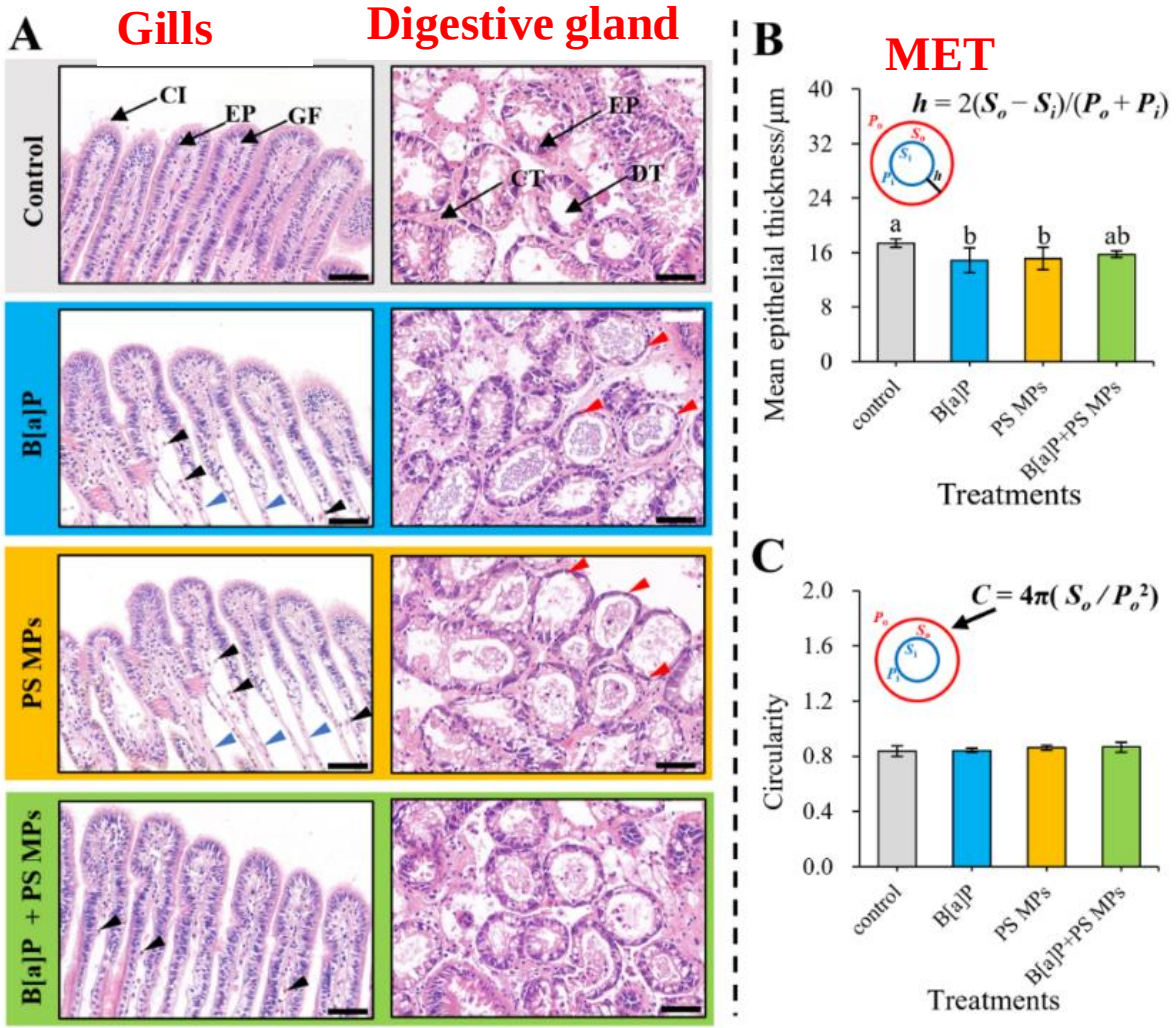
gills and digestive gland: histopathology



- **Thinning of gill filaments and a reduction in the mean epithelial thickness (MET) of digestive tubules following exposure to B[a]P alone and PS MPs alone.**
- **However, co-exposure to both substances alleviated these adverse effects.**

Wang et al., 2023, ***Aquatic Toxicology***, 106430: 256.

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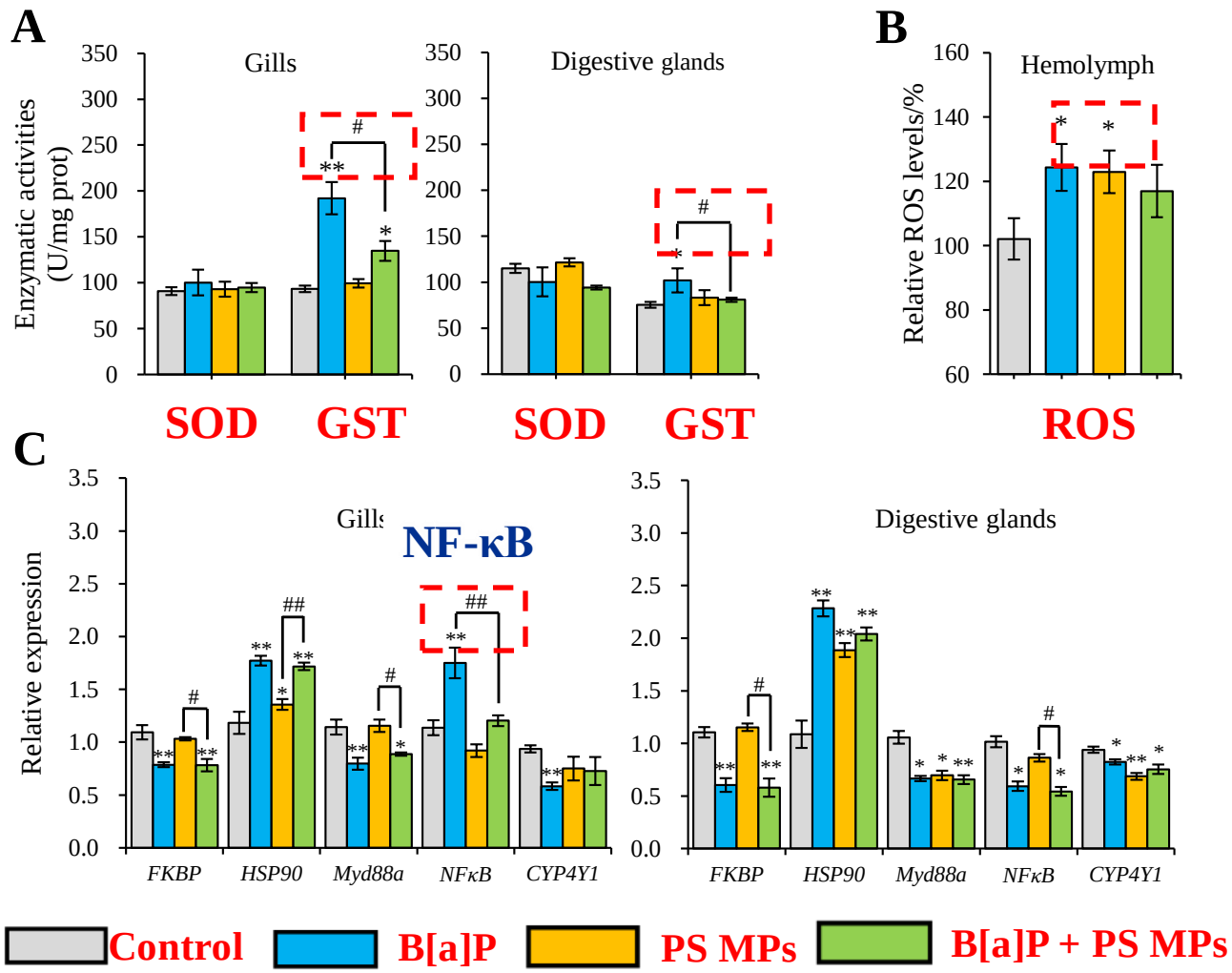
Molecular mechanism: oxidative stress and qRT-PCR

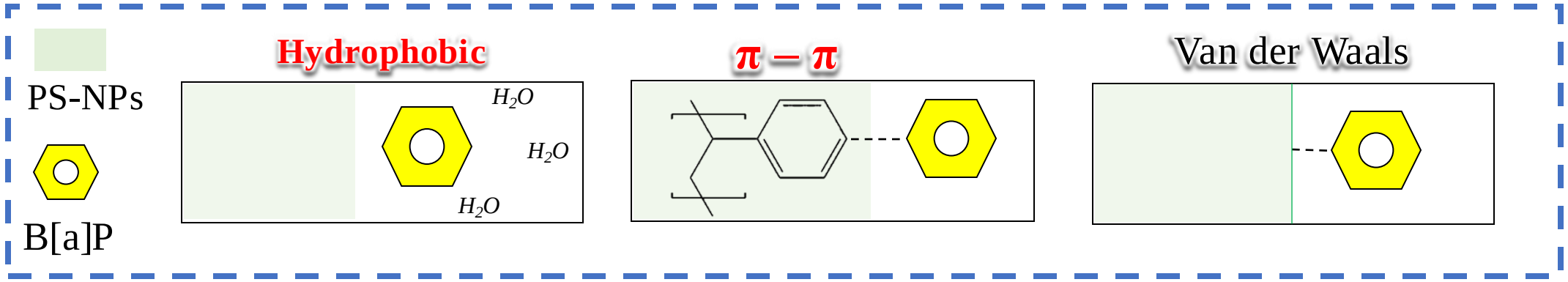


- **Single exposure to PS MPs or B[a]P resulted in increased ROS levels in haemolymph, whereas co-exposure alleviated these adverse effects.**
- **Mussels co-exposed to B[a]P and PS MPs exhibited significantly lower GST activity and down-regulated mRNA expression of NF-κB in gills compared to mussels exposed to B[a]P alone.**

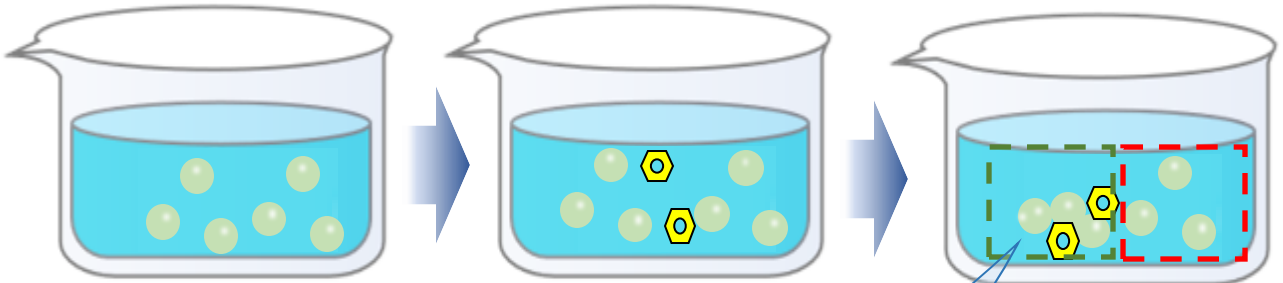
immune related

Wang et al., 2023, ***Aquatic Toxicology***, 106430: 256.

Interaction between PS-MPs and B[a]P



- The sorption of B[a]P onto the surface of MNPs is primarily driven by hydrophobic and π–π interactions.



increased hydrodynamic diameters of NPs and formation of more aggregates

the bioavailable concentration of B[a]P ↓ ?

Bioaccumulation of B[a]P

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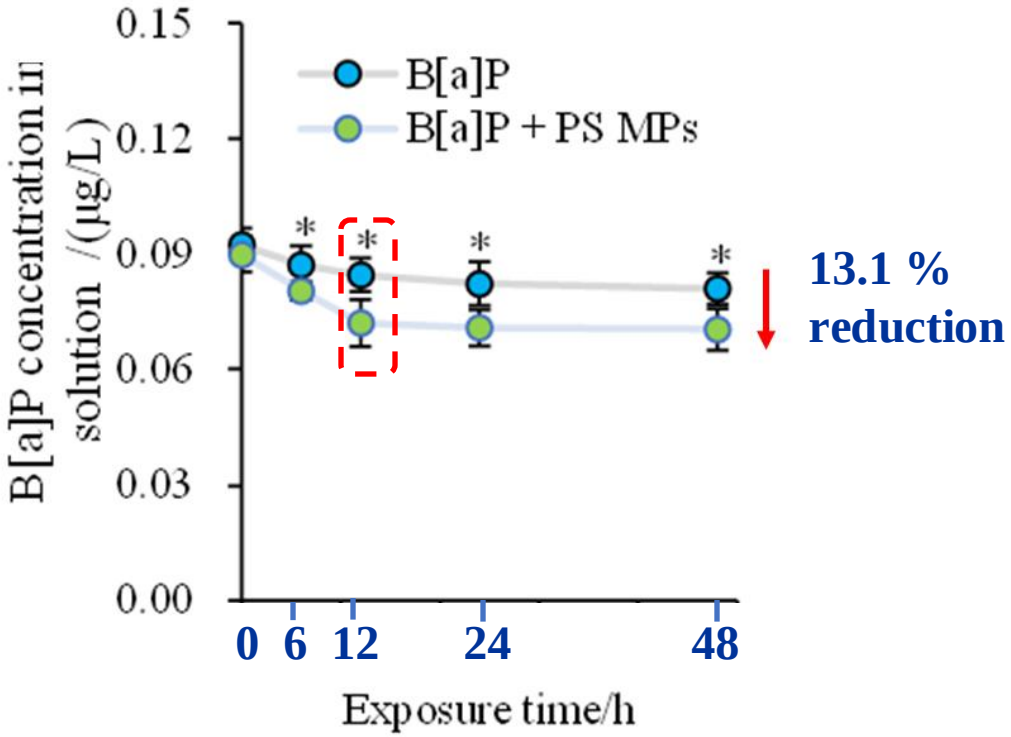
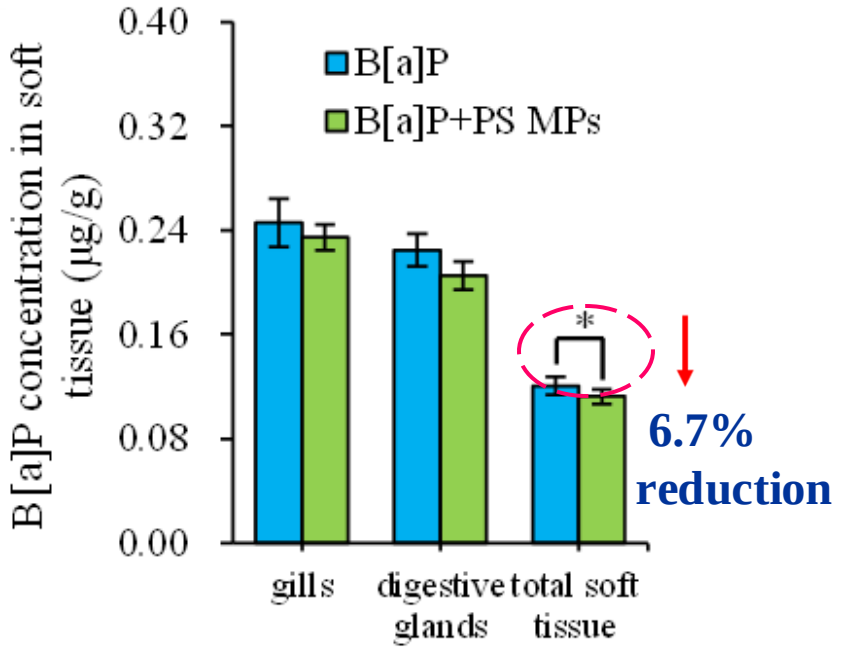


The waterborne concentrations of B[a]P



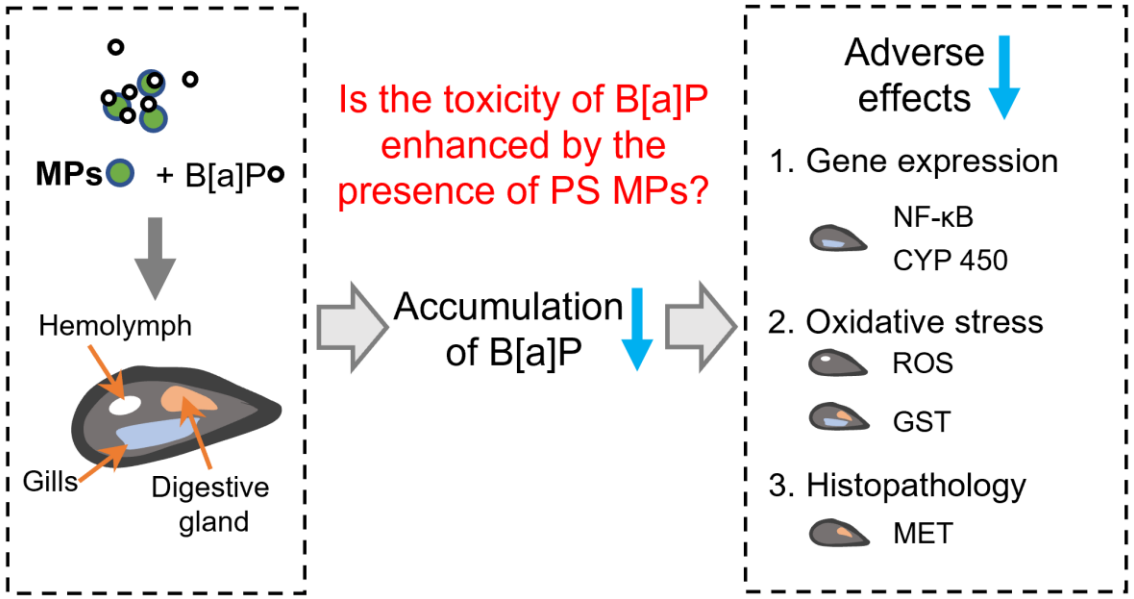
Bioaccumulation of B[a]P in mussels for 4 days

The bioaccumulation of B[a]P by mussels decreased in the presence of PS-MPs.

» **PS-MPs mitigated the toxic effects of B[a]P**

Summary

- **The co-presence of PS MPs reduced the adverse effects caused by B[a]P to some extent. PS MPs decreased the waterborne concentration of B[a]P and its bioaccumulation in adult mussels.**
- **Single exposure to B[a]P induced toxic effects in mussels, including histopathological alterations, oxidative stress, and dysregulation of mRNA expression. Polystyrene microplastics mitigate the adverse effects of benzo[a]pyrene on the tissues and cells of the marine mussel, *Mytilus galloprovincialis*.**



Acknowledgements

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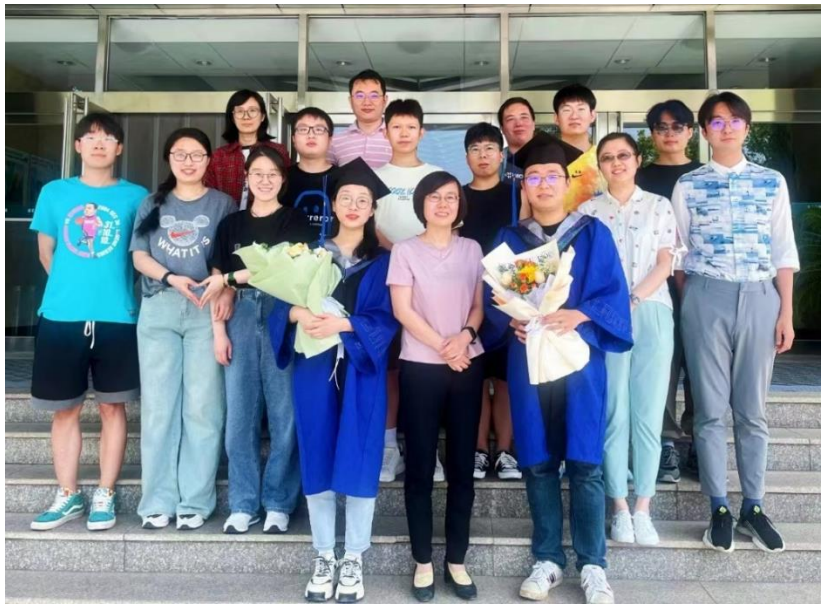
➢ Research Group



Marine Environmental Quality Criteria and Standard/海洋环境基准标准团队

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