

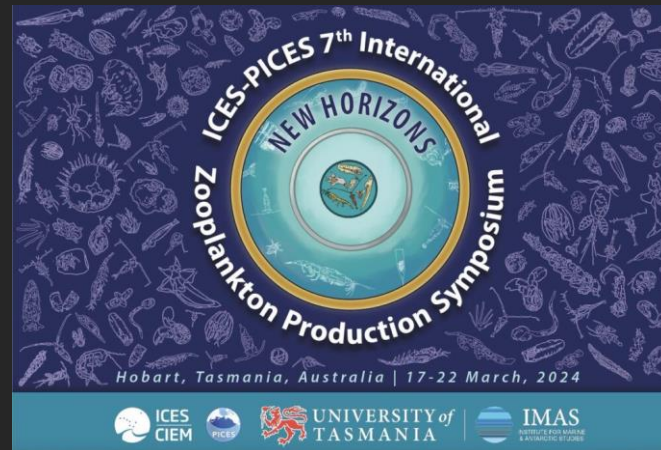
Searching for environmentally safer plastic additives using zooplankton as toxicity models

Antonio Paule*, Anna Cunill and Rodrigo Almeda

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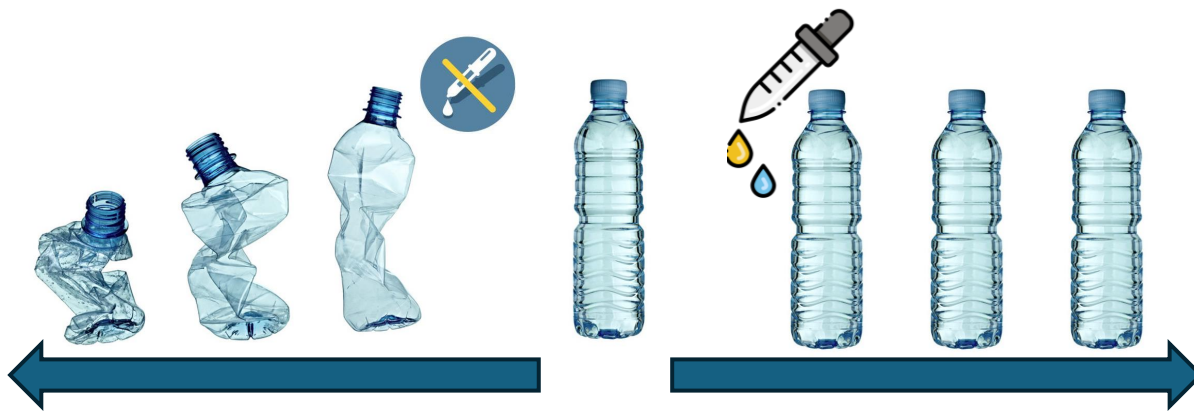
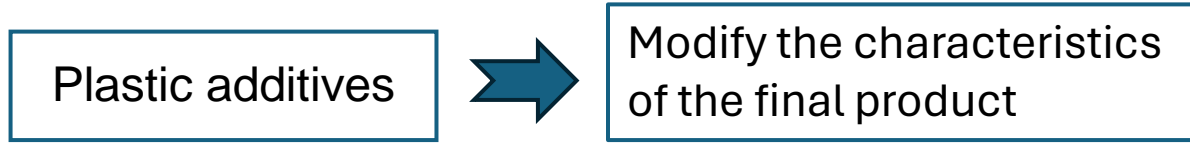


EOMAR
Grupo de Ecofisiología de
Organismos Marinos



UNIVERSIDAD DE LAS PALMAS
DE GRAN CANARIA

Introduction Plastic additives

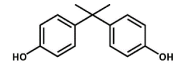


Enhancing properties

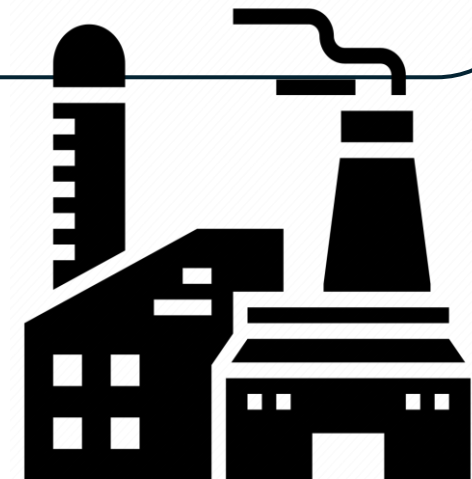
Physically



Chemically



Biologically



Introduction Plastic additives



No additives



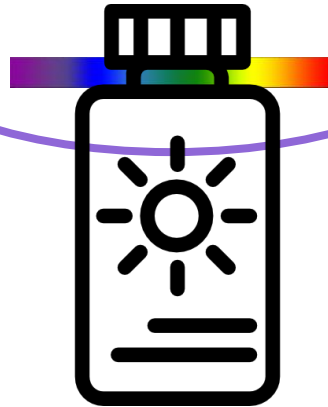
Additives

Introduction Plastic additives categories

Flame retardants



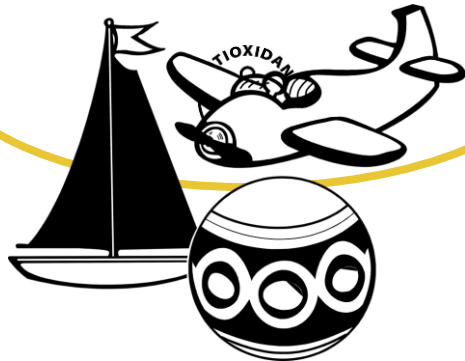
UV filters



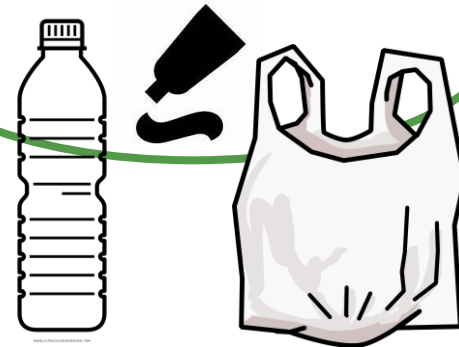
Non-stick



Antioxidants



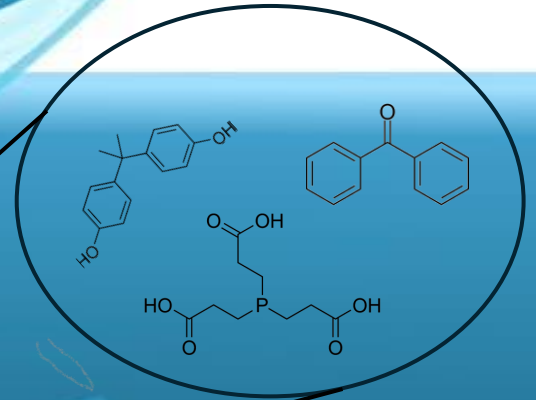
Plasticizers



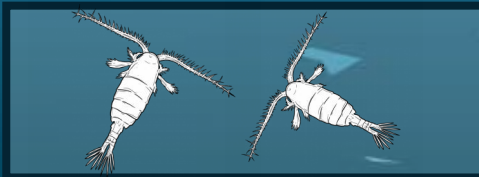
Introduction Plastic additives lixiviation



¡Leaching!



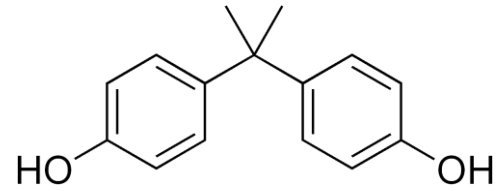
Copepods



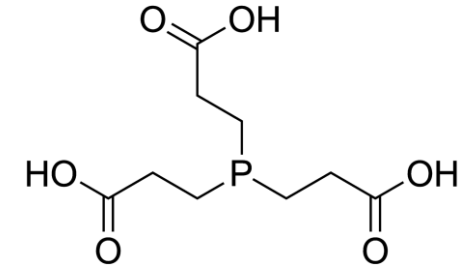
Sea urchins



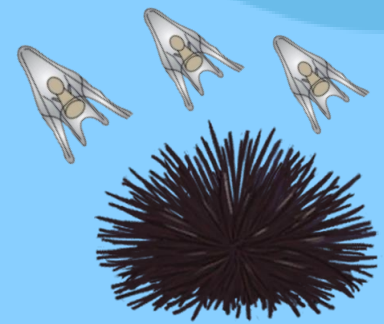
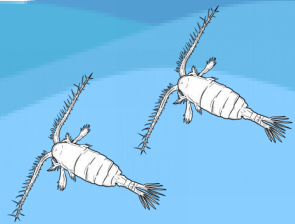
Objetives



Toxicity assesment of 5 **conventional** additives



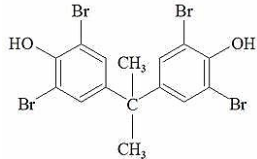
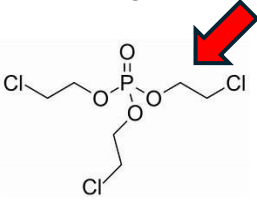
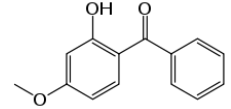
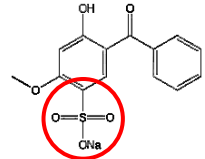
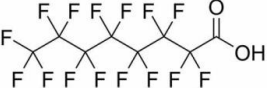
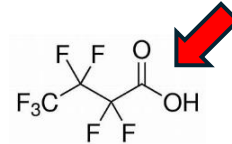
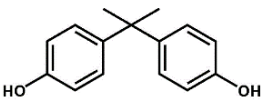
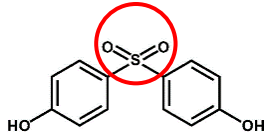
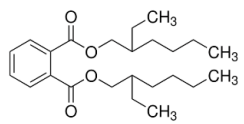
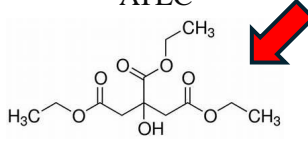
Analysis of the toxicity of 5 **alternative** additives



Methods Reactives

Conventional additives and alternatives chosen

- Strategies followed:
1. Sulfonic acid **addition**
 2. Carbon chain **shortening**
 3. Use of a **different** molecule

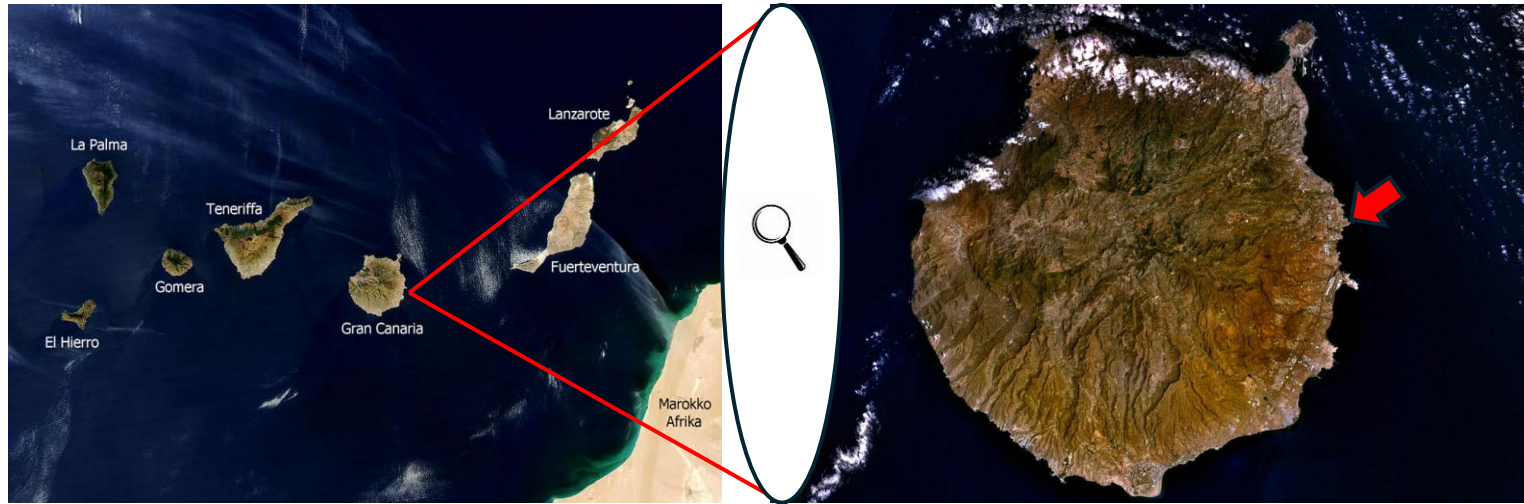
Function	Conventional additive	Alternative additive
Flame retardant	TBBPA 	TCEP 
UV filter	BP-3 	BP-5 
Non-stick coating	PFOA 	PFBA 
Antioxidant	BPA 	BPS 
Plasticizer	DEHP 	ATEC 

Methods Experimental organisms

1. *Arbacia lixula*



Collection



Melenara`s Pier, Gran Canaria, Canary Islands, Spain



Spawning



Injection with 0.5M of KCl into the coleom

¡No sexual dimorphism!



1. *Arbacia lixula*



Fertilization

♀

♂



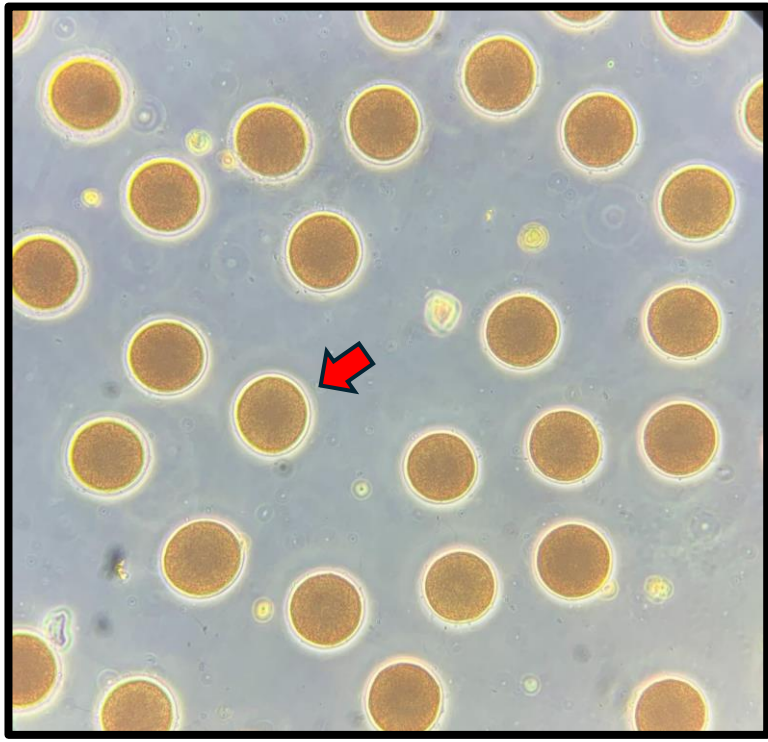
Eggs suspension

+



Diluted sperm

=



Fertilized eggs



Adult stage

2. *Acartia tonsa*



Lab maintenance:

- 0.1 μm filtered seawater (FSW)
- Salinity of 35 ‰
- Constant aeration
- Temperature of 20 °C
- Photoperiod of 12:12 h
- Fed on *Rhodomonas salina*
- Younger than one month

Exposure to additives



1 adult / ml



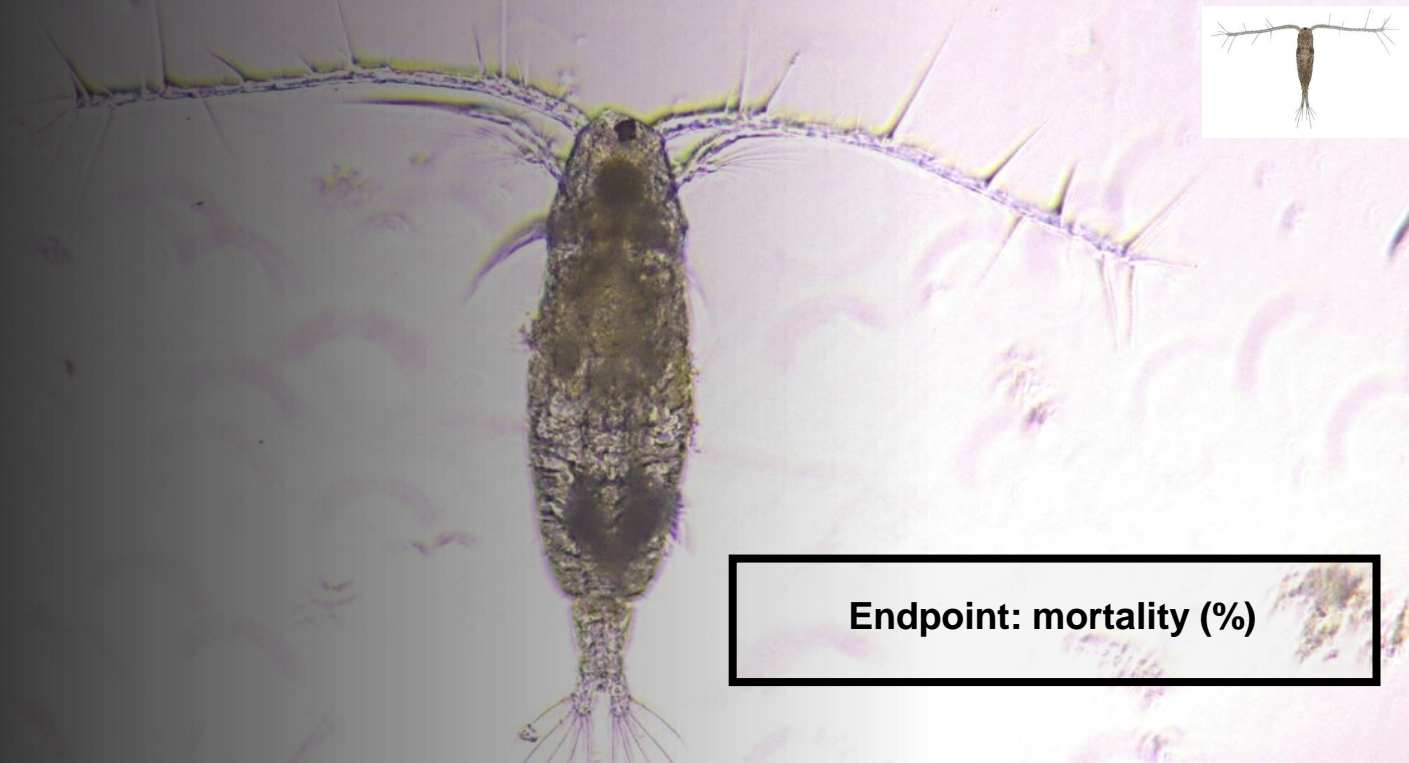
Five
[additive]



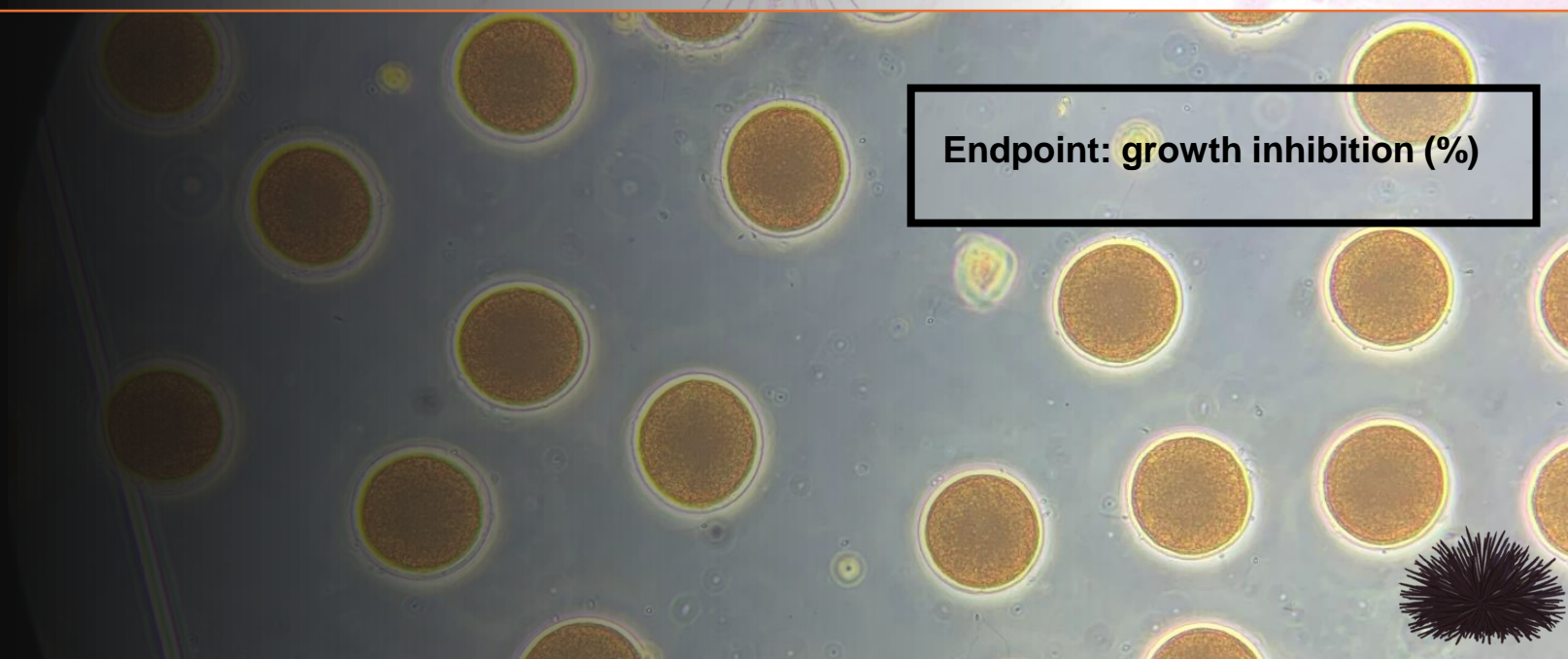
30 embryos
/ ml



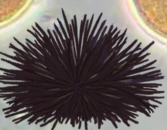
Five
[additive]



Endpoint: mortality (%)

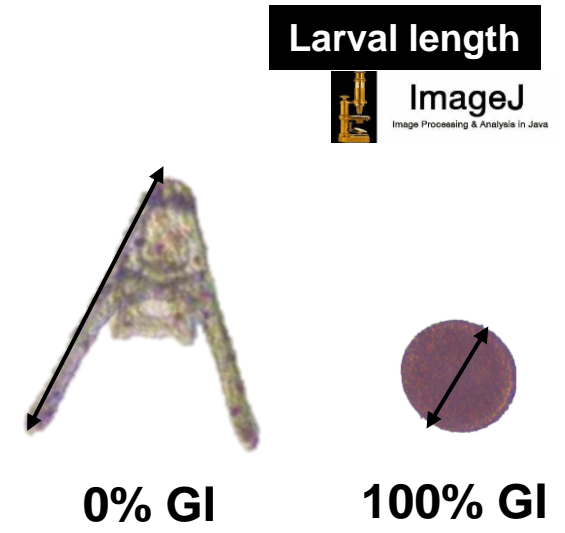


Endpoint: growth inhibition (%)

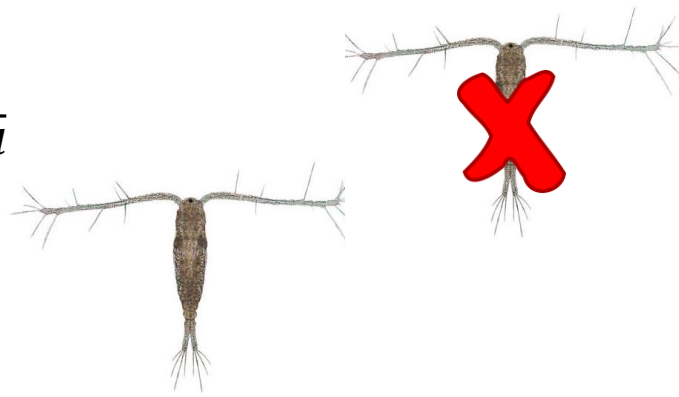




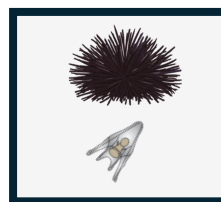
$$\% \text{ Growth Inhibition (GI)} = 100 - \frac{(\text{final length} - \text{eggs length}) \times 100}{\text{Control length} - \text{eggs length}}$$





$$\% \text{ Mortality (M)} = 100 - \frac{\text{Number of Alive copepod} \times 100}{\text{Number of aife copepod} + \text{number of dead copepod}}$$

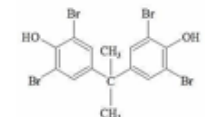
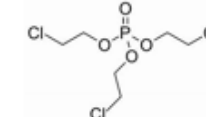


Results and discussion

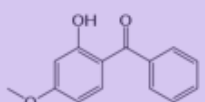


Conventional 

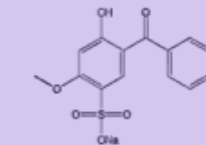
Alternative 

Conventional additive	Alternative additive
TBBPA	TCEP
	

BP-3



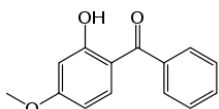
BP-5



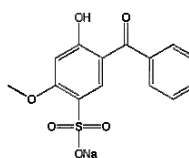
UV filter



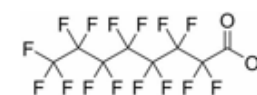
BP-3



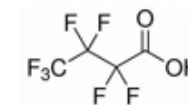
BP-5



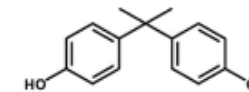
PFOA



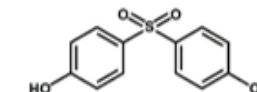
PFBA



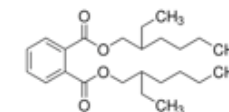
BPA



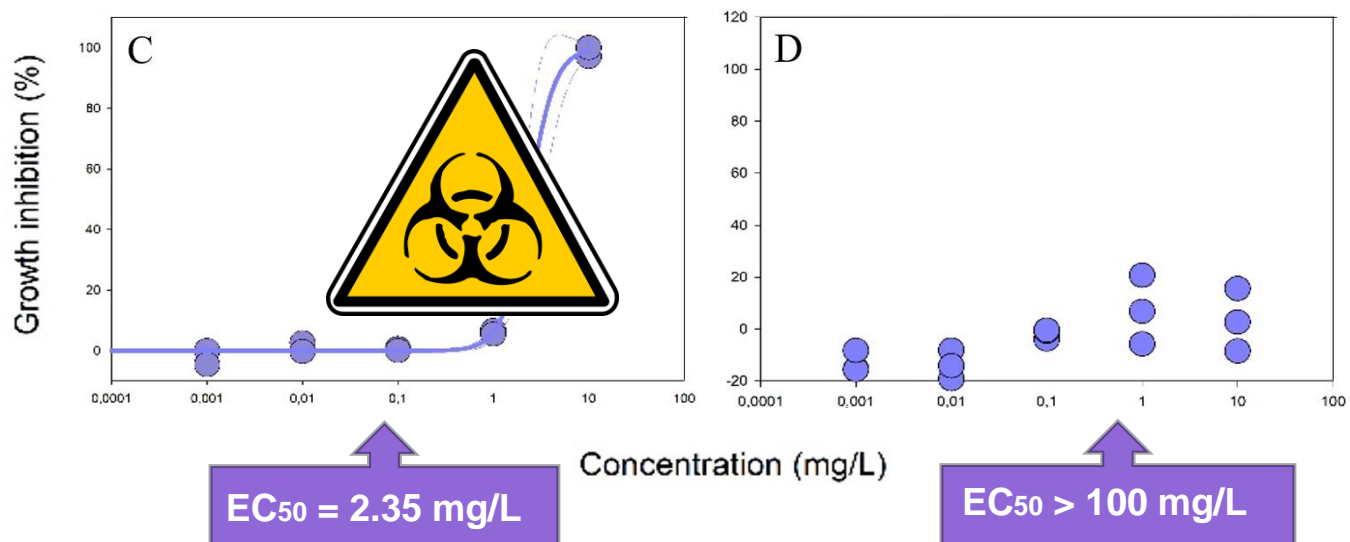
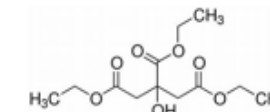
BPS

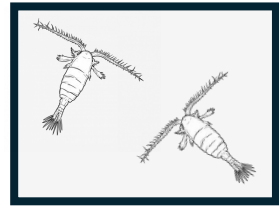


DEHP



ATEC





Conventional

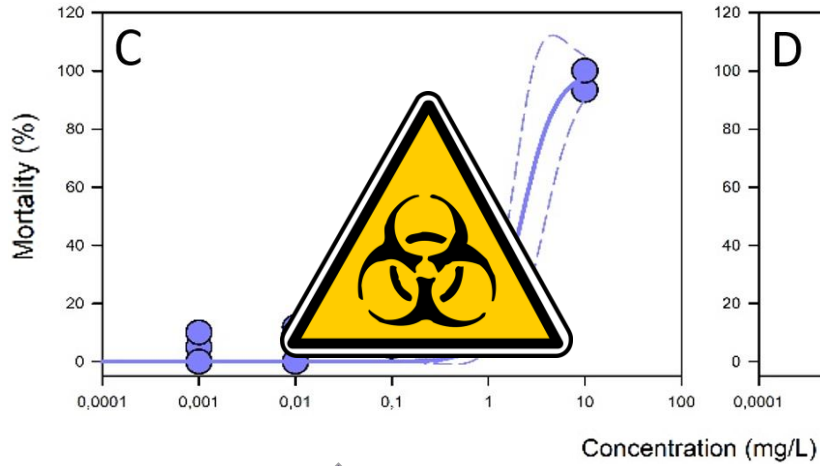
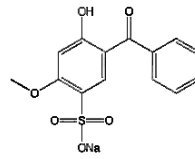
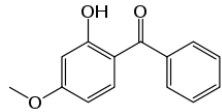
Alternative

UV filter

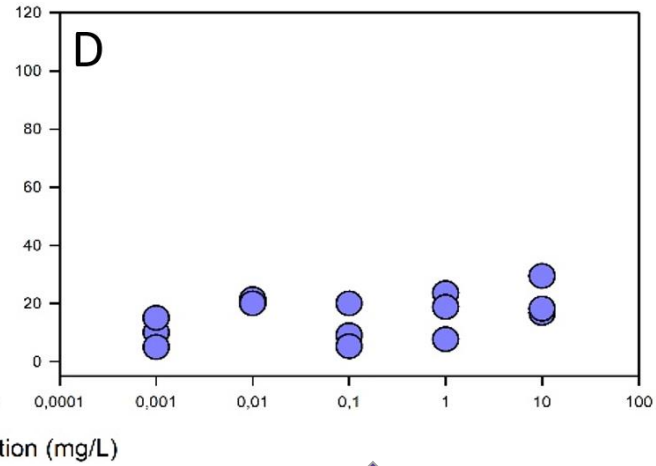


BP-3

BP-5



$LC_{50} = 1.7 \text{ mg/L}$

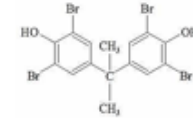


$LC_{50} > 100 \text{ mg/L}$

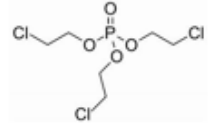
Conventional additive

Alternative additive

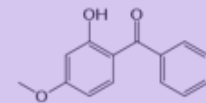
TBBPA



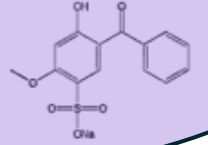
TCEP



BP-3



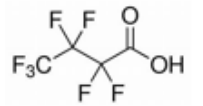
BP-5



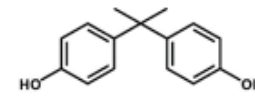
PFOA



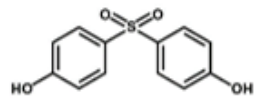
PFBA



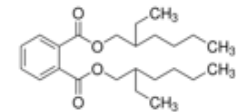
BPA



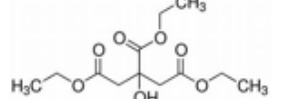
BPS



DEHP



ATEC

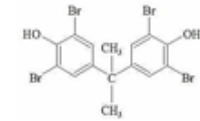




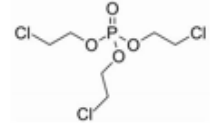
Conventional additive

Alternative additive

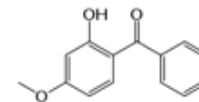
TBBPA



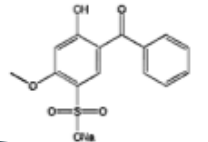
TCEP



BP-3



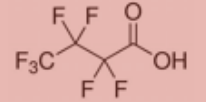
BP-5



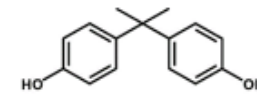
PFOA



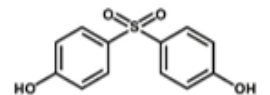
PFBA



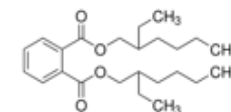
BPA



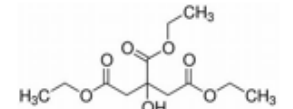
BPS



DEHP



ATEC



Conventional



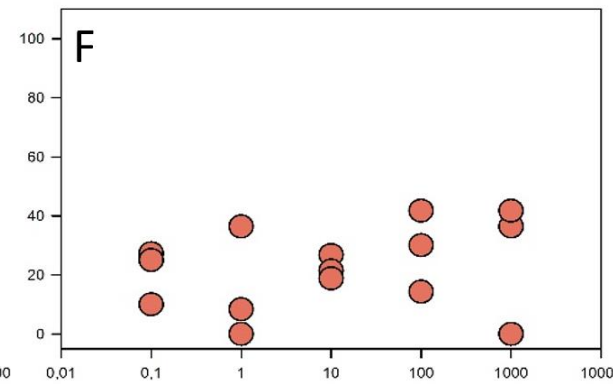
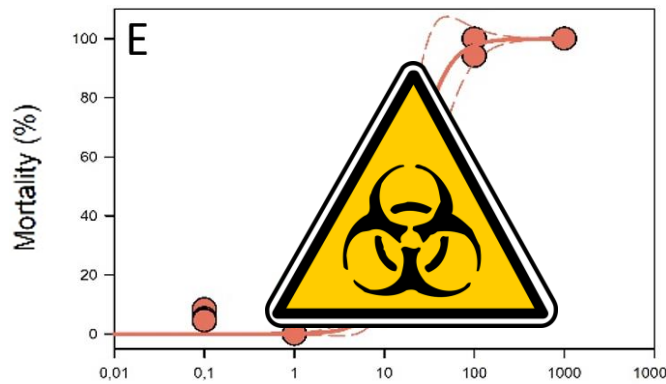
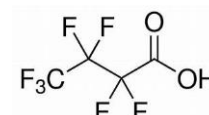
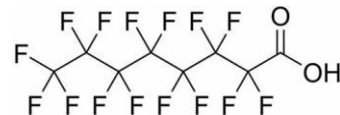
Alternative



Non-stick

PFOA

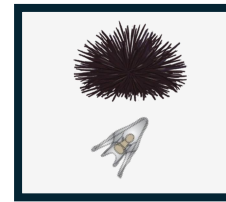
PFBA





LC50 = 19.99 mg/L

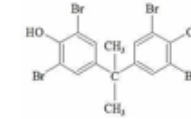
LC50 > 1000 mg/L

Results and discussion

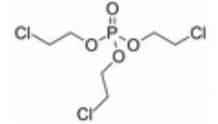


 Conventional additive	 Alternative additive
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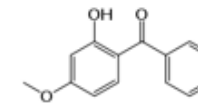
TBBPA



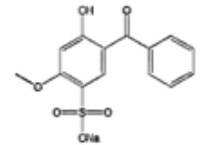
TCEP



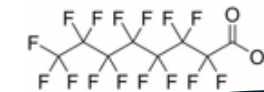
BP-3



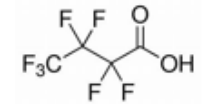
BP-5



PFOA




PFBA



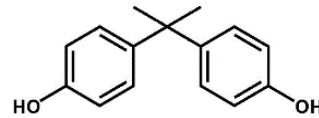
Antioxidant



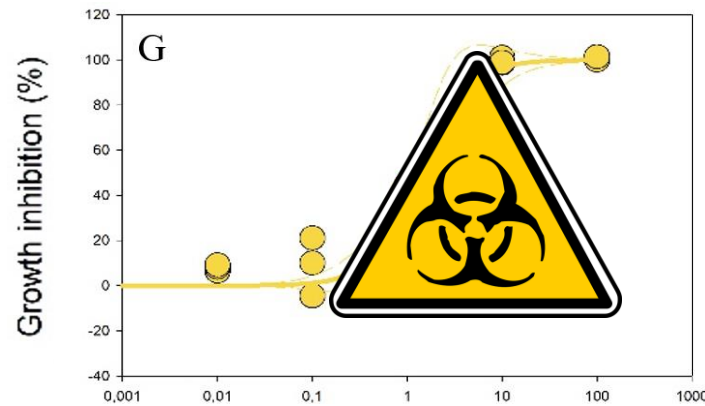
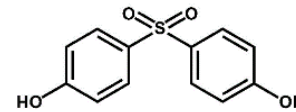
Conventional 

Alternative 

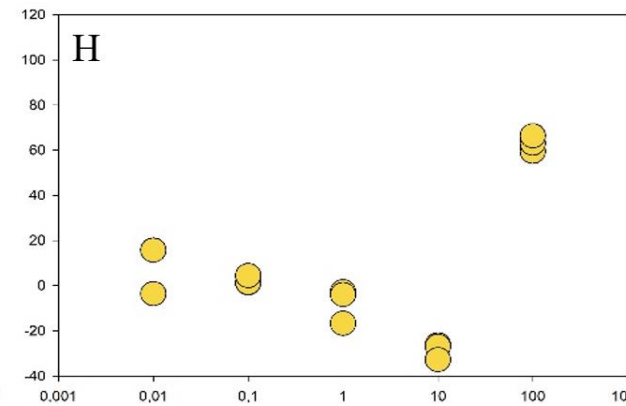
BPA



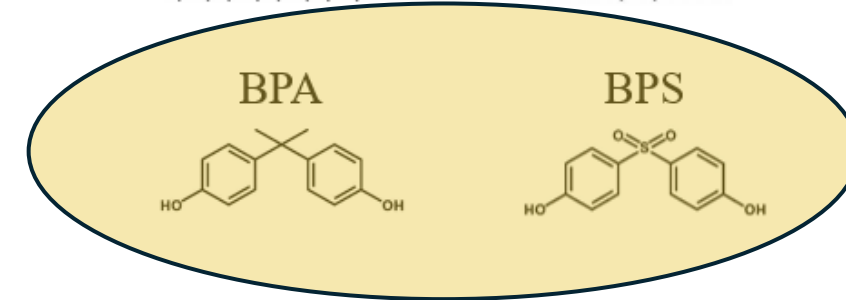
BPS



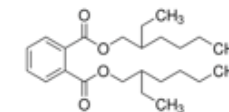
EC₅₀ = 1.37 mg/L



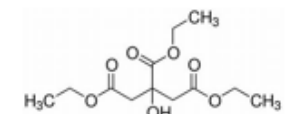
EC₅₀ = - mg/L

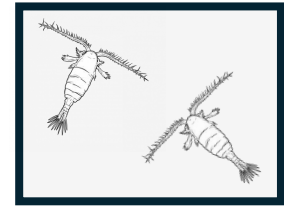


DEHP



ATEC



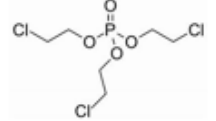
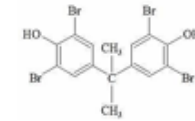


Conventional additive

Alternative additive

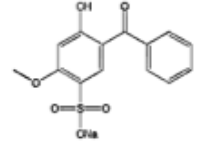
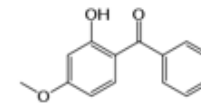
TBBPA

TCEP



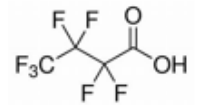
BP-3

BP-5



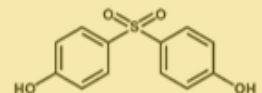
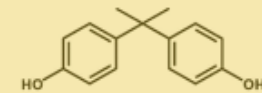
PFOA

PFBA



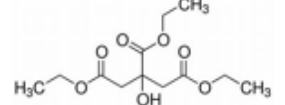
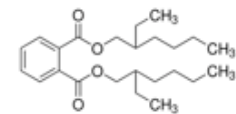
BPA

BPS



DEHP

ATEC



Conventional



Alternative

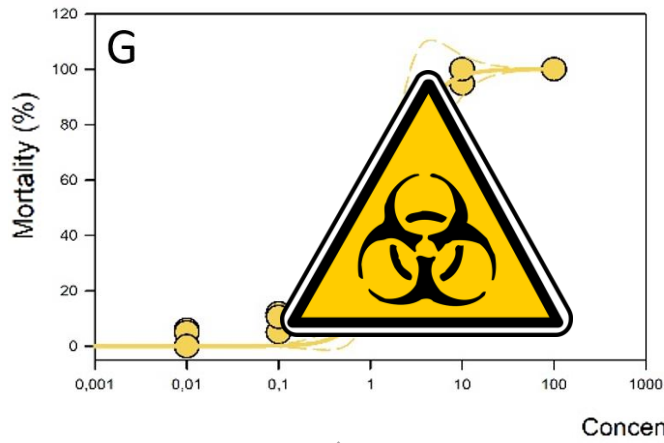
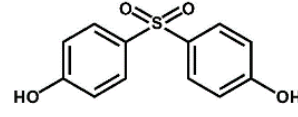
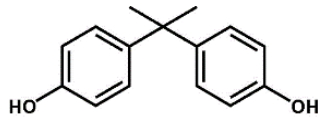


Antioxidant

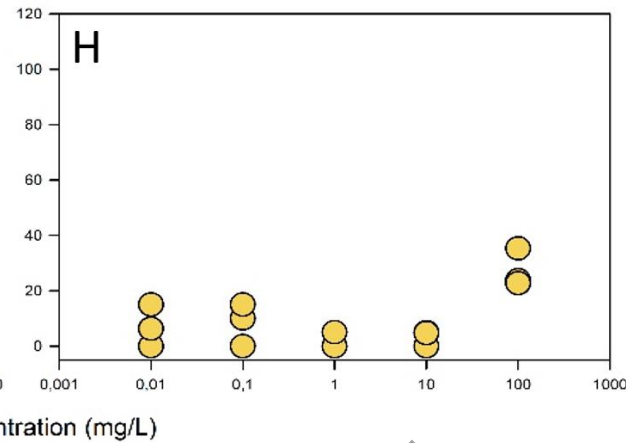


BPA

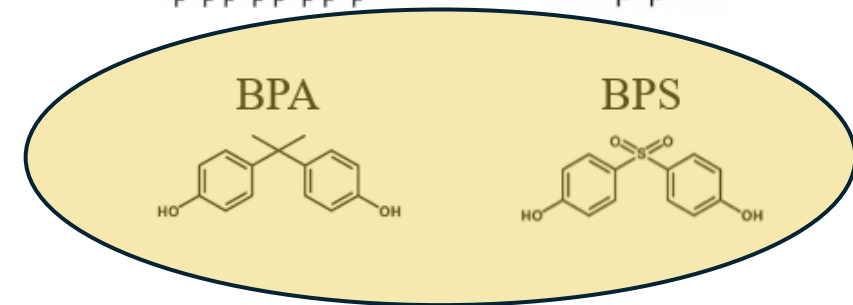
BPS



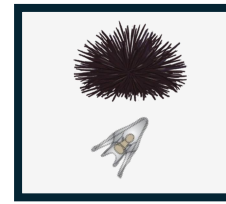
LC₅₀ = 1.86 mg/L




LC₅₀ > 100 mg/L



Results and discussion



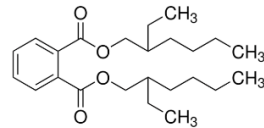
Conventional 

Alternative 

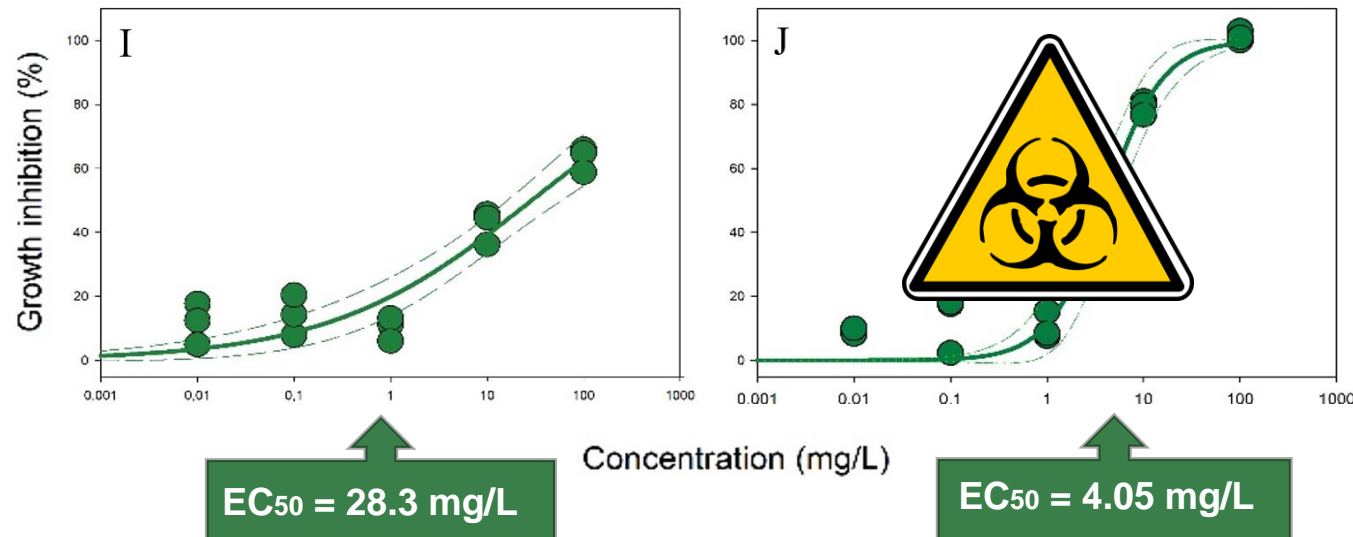
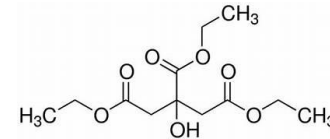
Plasticizer

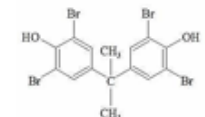
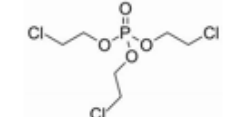
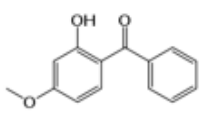
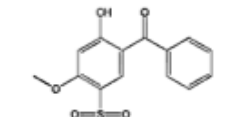
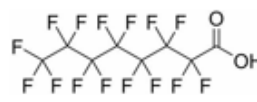
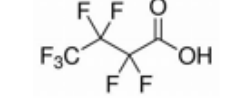
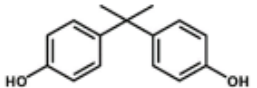
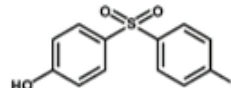


DEHP



ATEC



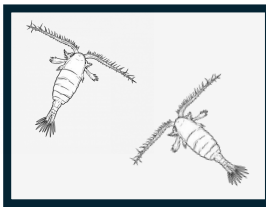
Conventional additive	Alternative additive
TBBPA 	TCEP 
BP-3 	BP-5 
PFOA 	PFBA 
BPA 	BPS 

DEHP


CC(C)CCOC(=O)c1ccc(cc1)C(=O)OCC(C)C

ATEC

CCOC(=O)CC(O)C(=O)OCC



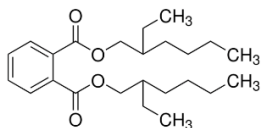
Conventional 

Alternative 

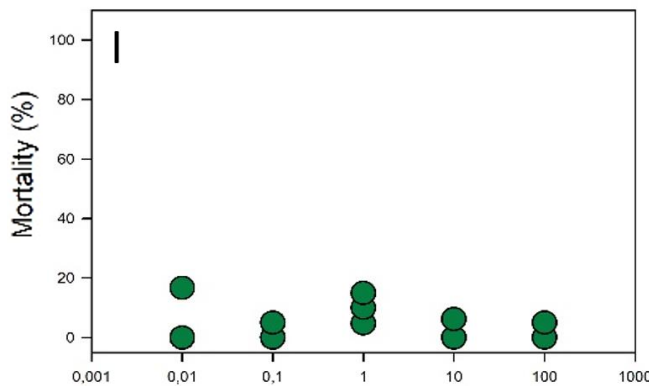
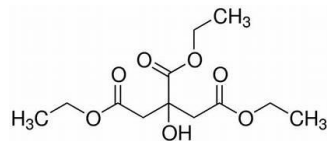
Plasticizer



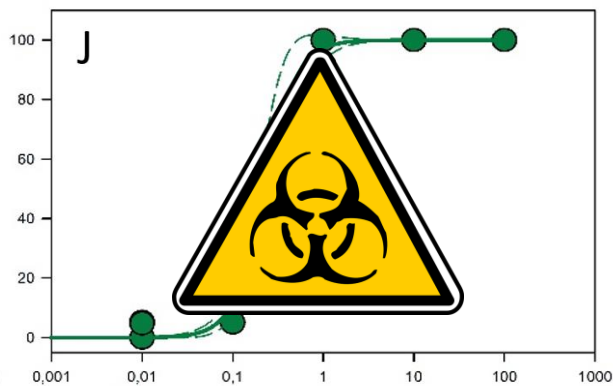
DEHP



ATEC



LC₅₀ > 100 mg/L



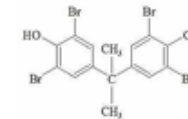
LC₅₀ = 0.23 mg/L



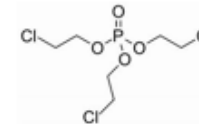
Conventional additive

Alternative additive

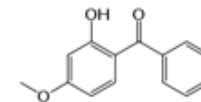
TBBPA



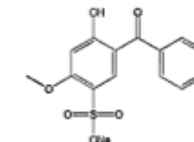
TCEP



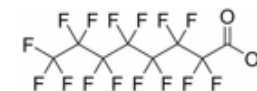
BP-3



BP-5



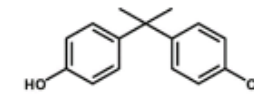
PFOA



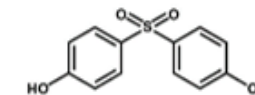
PFBA



BPA



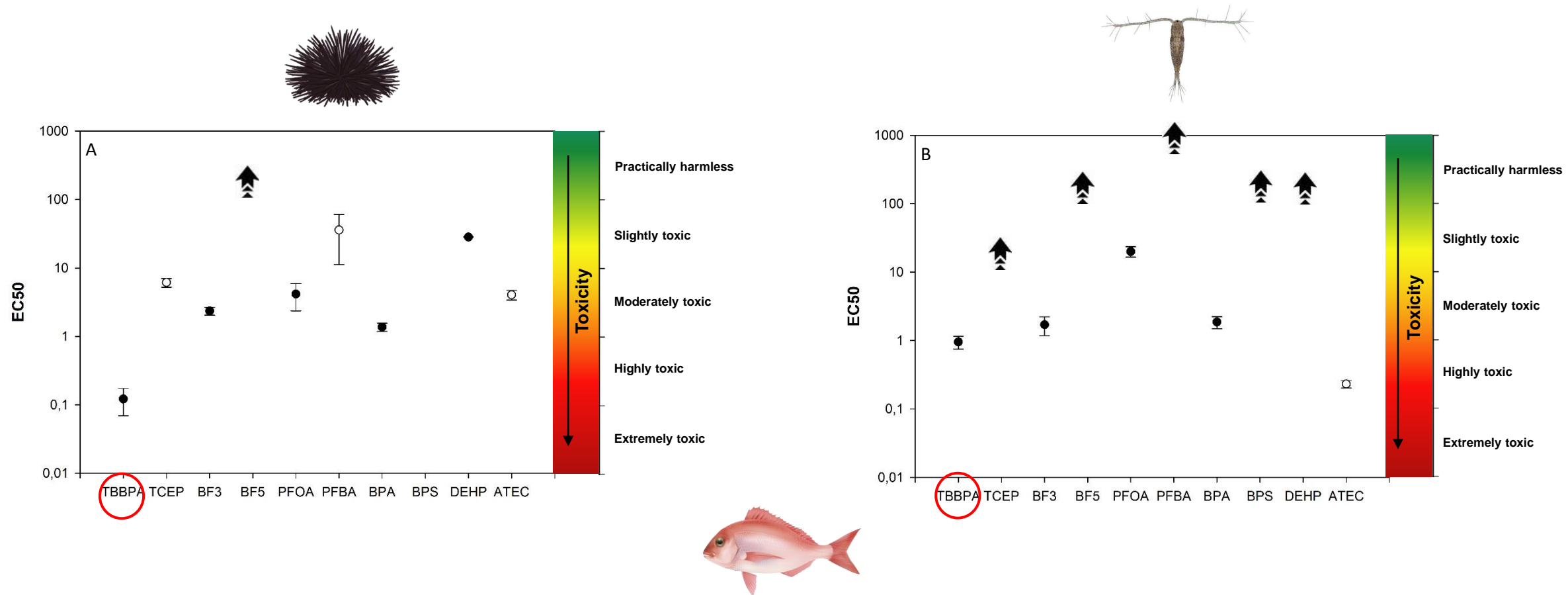
BPS



DEHP
ATEC

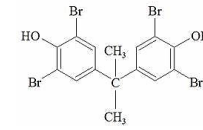
CCOC(=O)C(O)C(=O)OCC1=CC=CC=C1
CCOC(=O)C(O)C(=O)OCC1=CC=CC=C1

Results and discussion



Comparison between the EC₅₀ (mg/L) and their standard deviations for all the plastic additives at 48h exposure in *Arbacia lixula* embryos (A) and *Acartia tonsa* adults (B), in a toxicity scale proposed by Passino & Smith (1987) for ranking hazards.

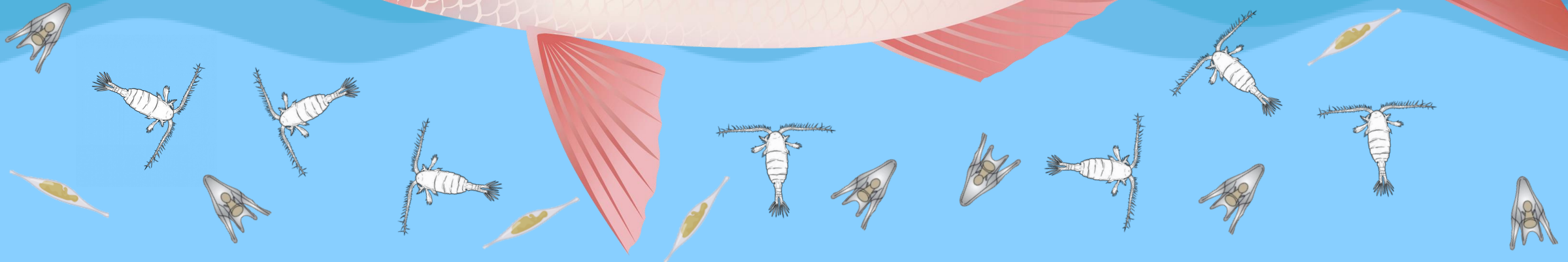
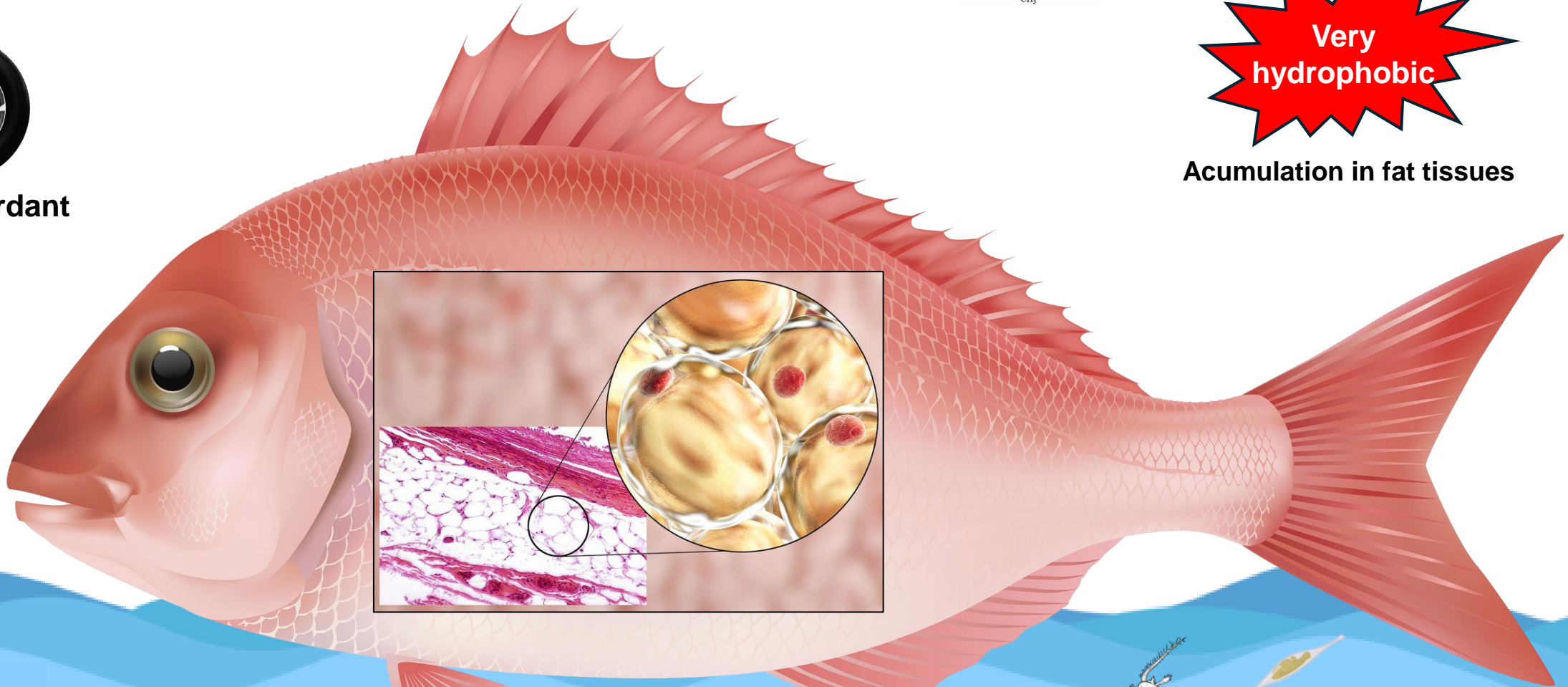
TBBPA (Tetrabromobisphenol A)



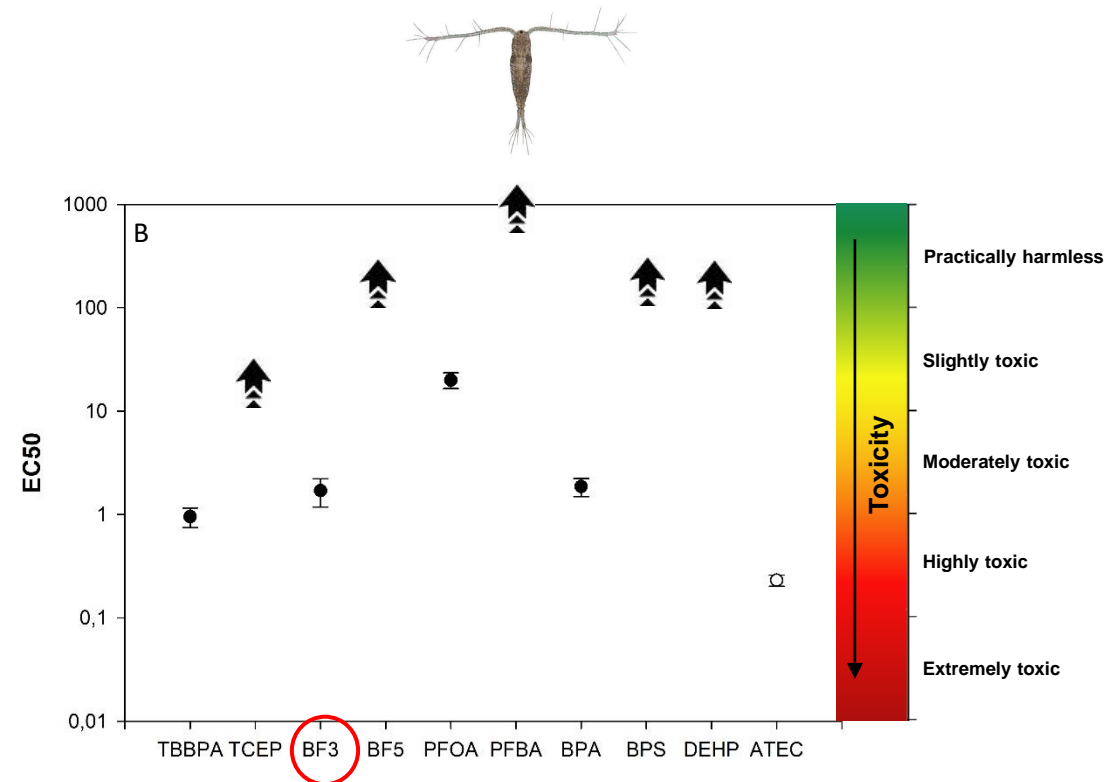
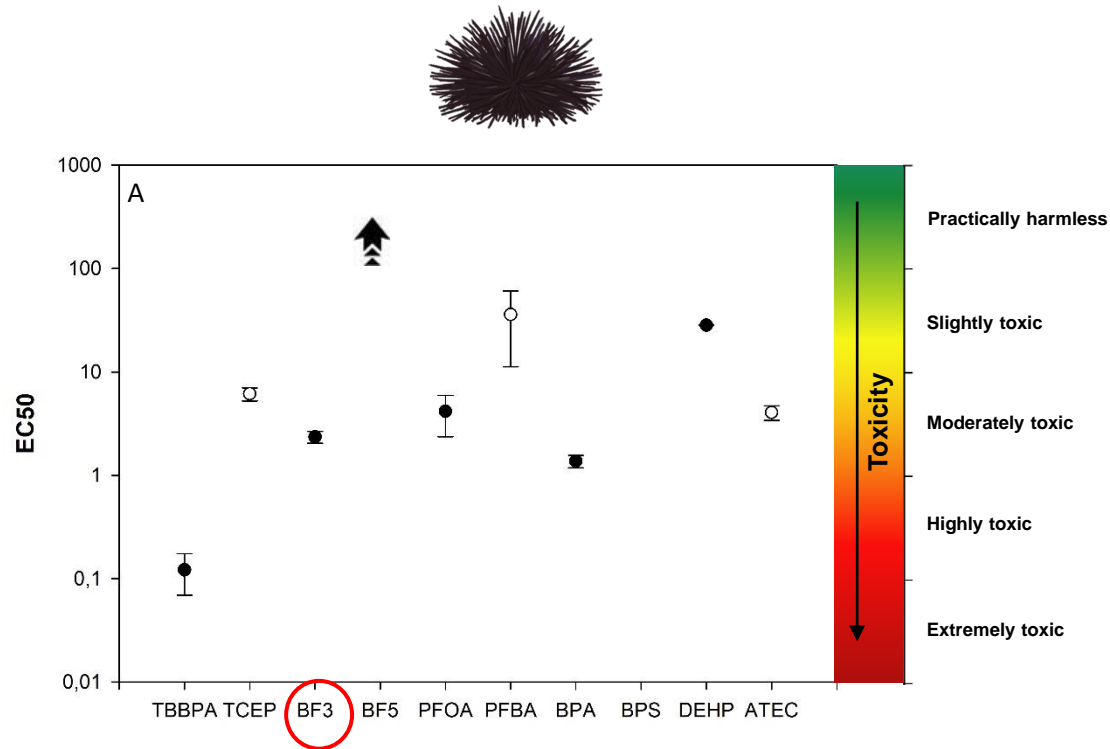
Flame retardant

Very hydrophobic

Acumulation in fat tissues



Results and discussion



Comparison between the EC₅₀ (mg/L) and their standard deviations for all the plastic additives at 48h exposure in *Arbacia lixula* embryos (A) and *Acartia tonsa* adults (B), in a toxicity scale proposed by Passino & Smith (1987) for ranking hazards.

BP-3 (Benzophenone 3) COc1ccc(O)c(C(=O)c2ccccc2)c1



UV filter



Trunk bay, St Thomas, US Virgin Islands

(Teoh et al., 2020)

¡Enviromentally relevant concentration!

[BP-3] = 1.4 mg/L



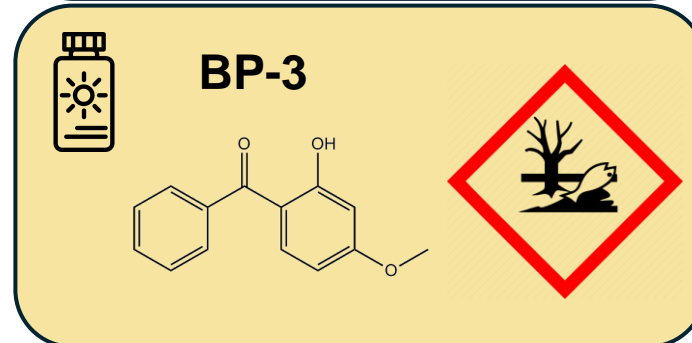
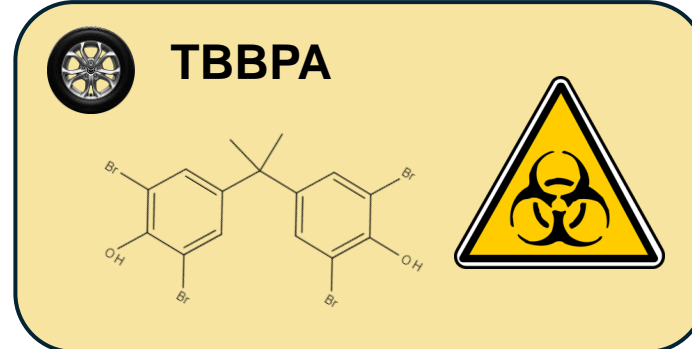
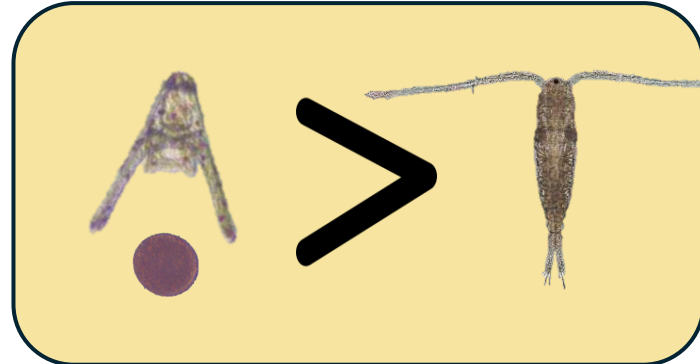
EC₅₀ = 2.4 mg/L



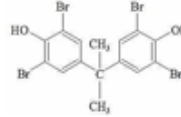
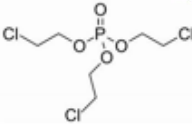
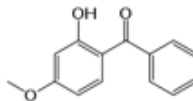
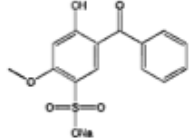

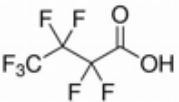
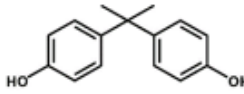
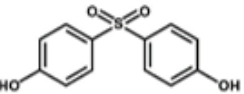
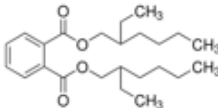
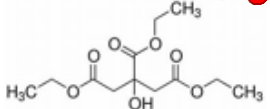


LC₅₀ = 1.7 mg/L

Conclusions

- 4 out of 5 alternative additives showed **less toxicity** than the conventionals
- Sea urchin embryos were **more sensitive** to additives than copepod adults
- TBBPA was **the most toxic** additive
- BP-3 has a great **ecological risk**



 Conventional additive	 Alternative additive
TBBPA 	TCEP ✓ 
BP-3 	BP-5 ✓ 
PFOA 	PFBA ✓ 
BPA 	BPS ✓ 
DEHP 	ATEC ✗ 

Acknowledgements

Looking for job opportunities in Australia!



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Thank you very much for your attention!