# Environmental Risk Assessment of Oxybenzone (Benzophenone-3) and Coral

Jennifer K. Saxe,<sup>1</sup> Kurt A. Reynertson,<sup>2</sup> Carys L. Mitchelmore,<sup>3</sup> Annaleise Conway,<sup>3</sup> Randy L. Jones,<sup>4</sup> and Larry A. Mullins<sup>4</sup>

<sup>1</sup>EcoSafety Sciences, <sup>2</sup>Johnson & Johnson Consumer Companies, Inc., <sup>3</sup>University of Maryland Center for Environmental Science, Chesapeake Biological Laboratory <sup>4</sup>Battelle Memorial Institute

### Introduction

Several researchers recently identified the sunscreen active ingredient, oxybenzone (benzophenone-3), as a potential risk to reef-building coral using *ad hoc* toxicity test methods and exposure modeling or environmental monitoring.

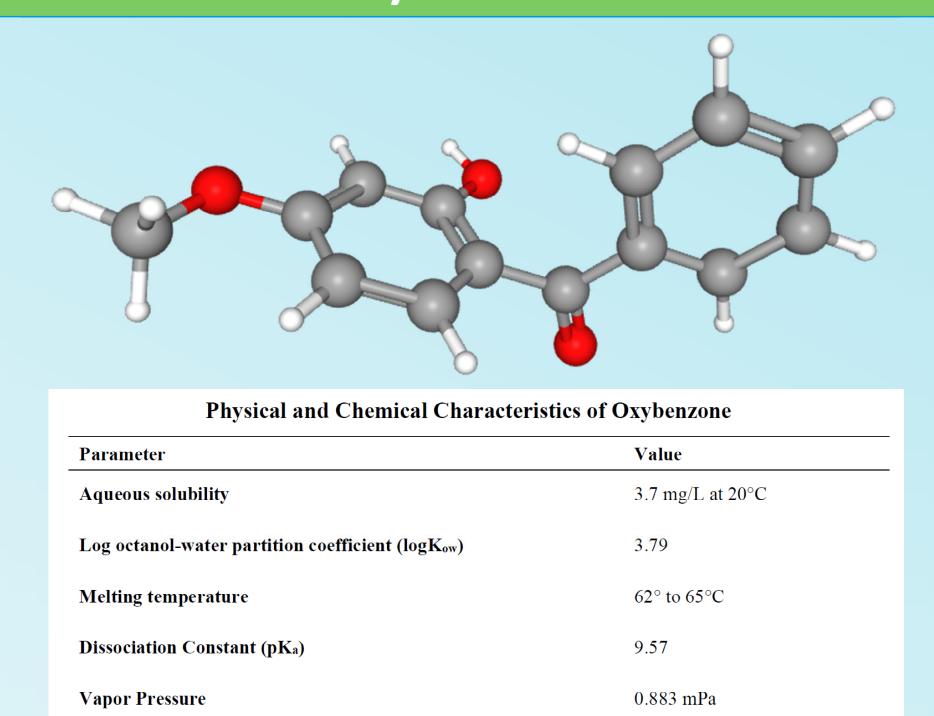
As a result, state and local legislators in the US have either enacted or are considering enacting bans on the sale of sunscreens containing oxybenzone.

There is a tension between the potential benefit to coral by using this precautionary approach - which has thus far relied on highly uncertain data - and the expected adverse human health outcome due to a reduction in the sun protection factor (SPF) of sunscreen products lacking oxybenzone.

To address this uncertainty, a comprehensive database of all relevant published data addressing environmental exposure and hazard of oxybenzone to coral species, plus newly generated oxybenzone toxicity data using adult coral nubbins, form the basis of this environmental risk assessment (ERA).

Select the Resources tab at ecosafetysciences.com to download a copy of this poster and the full list of references.

# Oxybenzone



Because of its photoactivity, it is used as a component of consumer products to absorb ultraviolet radiation.

Component of personal care products including: over-the-counter sunscreens, cosmetics, lotions, haircare products.

Component of other products including: plastic food packaging (e.g., polyethylene terephthalate bottles), paints, varnishes and sealants (e.g., for the protection of wood), and fabrics.

# Toxicity Estimate

Key Study	Study	Klimish Score	Klimish Score Primary Reason	Species	Life Stage	Duration	Endpoint	Value (μg/L)
	Danovaro <i>et al.</i> (2008)	3 – not reliable for decision- making	One exposure concentration only; Exposure was to an undisclosed mixture (e.g., expressed as 33 µL/L sunscreen lotion carrier containing 6% oxybenzone nominal exposure in water)	Acropora sp.	Adult	> 24 hours	Bleaching (no statistical benchmark derived)	2000-3000 (uncertain)
		. 0	- p,	Acropora pulchra	Adult	> 48 hours	Bleaching (no statistical benchmark derived)	3000-4500 (uncertain)
	Downs <i>et al.</i> (2016)	3 – not reliable for decision- making	Exposure concentration not measured; No documentation of temperature control; Test system designed for larval fish; Co-solvent DMSO used, and Kais <i>et al.</i> (2013) showed a pattern of DMSO-facilitated excess permeation into the chorion and embryo of zebrafish in the same test method used by Downs' group, finding tracer compound present in test organisms at all DMSO concentrations but not in DMSO-free controls	Stylophora pistillata	Larval	24 hours	LC <sub>50</sub>	139 (light) 799 (dark)
				Stylophora pistillata	Larval	24 hours	Deformation EC <sub>50</sub>	49 (light) 137 (dark)
	He <i>et al</i> . (2019)	3 – not reliable for decision- making	Exposure concentration not measured; oxybenzone decreased to 3% or less (as low as undetectable) of nominal concentration by the end of the experiment; no chemical analysis performed during the experiment, only before and after.	Seriatopora caliendrum	Larval	14 days	Bleaching LOEC	1000
				Pocillopora damicornis	Larval	14 days	Bleaching, Mortality LOEC	> 1000
				Seriatopora caliendrum Pocillopora damicornis	Adult Adult	7 days 7 days	Bleaching LOEC Mortality, zooaxanthellae density LOEC	1000 > 1000
<b>&gt;</b>	Conway <i>et al.</i> (2019)	2 – reliable with	Well-documented and follows rigorous protocols, but not GLP and does not use validated test guideline (none exist for coral)	Galaxea fascicularis	Adult	4 days	LC <sub>50</sub>	5690 5880

Three published studies describe effects to coral species after exposure to oxybenzone or mixtures containing oxybenzone. While providing information on the types of effects expected to occur, none were designed in a way to use in a quantitative environmental risk assessment.

Conway et al. recently performed a study designed for use in quantitative risk assessment – the key study in this ERA – fully described in platform presentation 6 of the session *Concentrations and Impacts of UV Filters in Aquatic Environments* at this conference.

### Conclusions

Newly developed toxicity data with *Galaxea fascicularis* are sufficiently rigorous to allow quantitative risk assessment for coral exposed to oxybenzone, showing a 4-day  $LC_{50}$  of 5690 and 5880  $\mu$ g/L in two separate studies.

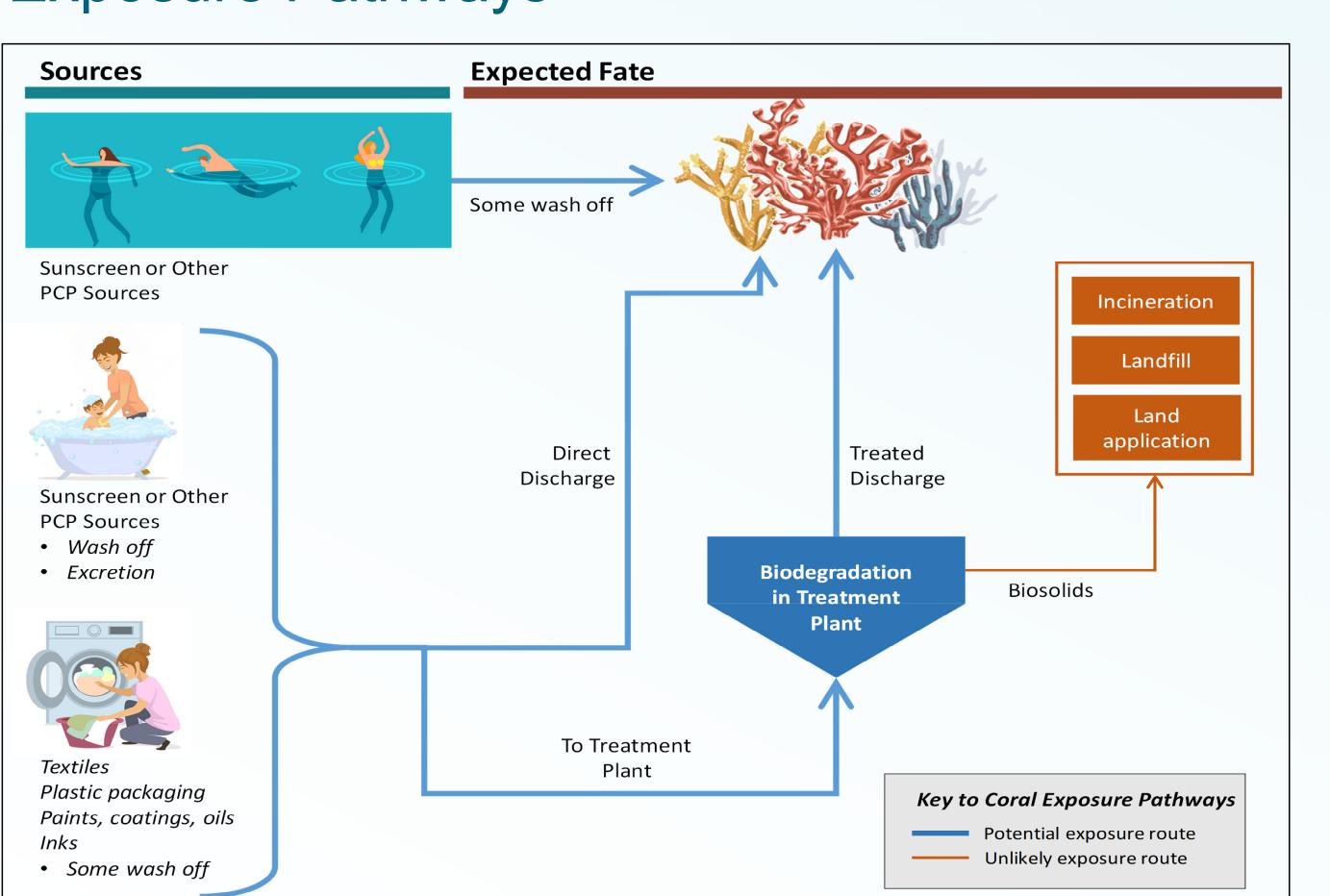
While modeling approaches are currently being undertaken to estimate coral reef exposure based on sunscreen use patterns, monitoring data provide a rough estimate of exposure and risk.

Reasonable worst case exposure is expected in the Southeastern US during summer where the highest average and maximum measured concentrations in shallow (**non-reef**) beach water were 1.5 and 2.2  $\mu$ g/L, respectively.

The highest concentration in Hawaiian reef areas was significantly lower: 0.143 µg/L.

None of these scenarios supports a conclusion that oxybenzone currently poses a risk to coral, even if using an assessment factor of 1000 (*i.e.*, a predicted no effect concentration of 5.7 to 5.9  $\mu$ g/L)

# Exposure Pathways



### Skin Rinse-Off Study Underway

Commercial sunscreen applied to porcine skin patch

15-minute dry time

Four rinse-dry cycles in agitated seawater at 28 °C

Total rinsing time 30 minutes over a 60-minute span



Commercially-available lotion and spray tested for UV filter compounds rinsed off including oxybenzone

Initial results available for higher than typical application rate (2 mg/cm<sup>2</sup>)

### Improved Exposure Modeling Ongoing

Exposure Estimate

Danovaro *et al.* (2008) are widely cited for their exposure estimate in which they assume sunscreen is applied at the recommended rate of **2 mg/cm²** and **25%** of applied sunscreen washes off into seawater.

However, actual application rates are known to be around **0.5 mg/cm²** (*e.g.*, Autier *et al.*, 2001; Lademann *et al*, 2004; Diaz *et al.*, 2012; Heerfordt *et al.*, 2017 )

Our current skin rinse-off study shows that even at the higher, 2 mg/cm<sup>2</sup> application rate, < 10% of oxybenzone in commercial sunscreen lotion and spray applied to porcine skin can be detected in seawater. Most is removed from skin only with a solvent wash.

Tests with additional formulas and more realistic application rates (around **0.5 mg/cm<sup>2</sup>**) are ongoing.

### Monitoring-Based Exposure Estimate

Lacking data on the magnitude of other sources, oxybenzonecontaining sunscreen was assumed to be the most significant source in seawater, and J&J Consumer, Inc.'s sunscreen sales were assumed to represent overall patterns of sunscreen use.

This model suggests oxybenzone exposure potential in seawater is greatest, worldwide, in the Southeastern US during summer.

Reasonable maximum exposure: One group performed two monitoring studies at beaches (not reef areas) in the Southeastern US during summer, yielding average shallow concentration range: 0.3 to 1.5 µg/L (four sites) and maximum: 2.2 µg/L (Bratkovics *et al.*, 2011, 2015).

Central tendency exposure: Best available reef area study was conducted in Hawaii, yielding average and maximum shallow concentrations at Waikiki Beach: 0.071 and 0.143 µg/L, respectively (Mitchelmore *et al.*, 2019).

### Model-Based Verification of Monitoring

Downs *et al.* (2016) is widely cited for anomalous, high monitoring values (up to 1395 µg/L) detected in reef areas of the Virgin Islands. The same site was studied by Bargar *et al.*, (2015) with results more than two orders of magnitude lower.

To determine the more reliable study, modeling was performed by Maples-Reynolds *et al.* (2019) and assisted by the authors.

Downs et al. (2016) report 180 swimmers at the site.

Maples-Reynolds' *et al.* (2019) highly conservative model of rinse-off and dilution at the site indicate more than **8400** swimmers using 2 mg/cm<sup>2</sup> sunscreen with 100% rinse-off and four reapplications per day would need to be present to yield 1395 μg/L oxybenzone in the water column.

The 1395 µg/L value does not accurately represent exposure to oxybenzone in the water column due to sunscreen use.

#### Environmental Risk Assessment of Oxybenzone (Benzophenone-3) and Coral

Jennifer K. Saxe,<sup>1</sup> Kurt A. Reynertson,<sup>2</sup> Carys L. Mitchelmore,<sup>3</sup> Annaleise Conway,<sup>3</sup> Randy L. Jones,<sup>4</sup> and Larry A. Mullins<sup>4</sup>

#### **Abstract**

Several researchers recently identified the sunscreen active ingredient, oxybenzone, as a potential risk to reef-building coral using ad hoc toxicity test methods and exposure modeling or environmental monitoring. As a result, state and local legislators in the US have either enacted or are considering enacting bans on the sale of sunscreens containing oxybenzone. There is a tension between the potential benefit to coral by using this precautionary approach – which has thus far relied on highly uncertain data - and the expected adverse human health outcome due to a reduction in the sun protection factor (SPF) of sunscreen products lacking oxybenzone. To address this uncertainty, a comprehensive database of all relevant published data addressing environmental exposure and hazard of oxybenzone to coral species, plus newly generated oxybenzone toxicity data using adult coral nubbins, form the basis of this environmental risk assessment (ERA). The worldwide reasonable worst case exposure scenario was identified as the southeastern US during summer and is the focus of this evaluation. The ERA uses multiple regulatory paradigms from Europe and the US and the full aquatic toxicity database for oxybenzone with hard corals and surrogate species to characterize hazard potential. A combination of modeling using oxybenzone wash-off measurements from skin to which sunscreen was applied and environmental monitoring studies are used to characterize exposure potential. The ERA results are meant to inform legislative and regulatory efforts by identifying conditions under which there is any potential benefit expected to coral from restrictions on the sale of oxybenzone-containing sunscreens. This information is intended to assist decision-makers in balancing against the potential human health cost of any such restriction.

#### References

Autier P, Boniol M, Severi G, Dorea J-F. 2001. Quantity of sunscreen used by European students. *Brit. J. Dermatol.* 144: 288-291.

Bargar TA, Alvarez DA, Garrison VH. 2015. Synthetic ultraviolet light filtering chemical contamination of coastal waters of Virgin Islands national park, St John, US Virgin Islands. *Marine Pollution Bull.* 101(1): 193-199.

Bratkovics S, Sapozhnikova Y. 2011. Determination of seven commonly used organic UV filters in fresh and saline waters by liquid chromatography-tandem mass spectrometry. *Anal. Methods*, 3:2943-2950.

<sup>&</sup>lt;sup>1</sup>EcoSafety Sciences

<sup>&</sup>lt;sup>2</sup>Johnson & Johnson Consumer Companies, Inc.

<sup>&</sup>lt;sup>3</sup>University of Maryland Center for Environmental Science, Chesapeake Biological Laboratory

<sup>&</sup>lt;sup>4</sup>Battelle Memorial Institute

Bratkovics S, Wirth E, Sapozhnikova Y, Pennington P, Sanger D. 2015. Baseline monitoring of organic sunscreen compounds along South Carolina's coastal marine environment. *Mar Pollut Bull*. 101(1):370-377.

Conway A, Mitchelmore C, Gonsior M, Heyes A, Clark C. 2019. Investigating the Toxicity of the UV filter Benzophenone-3 (BP-3 or oxybenzone) on the hard coral *Galaxea fascicularis*. Presentation at the SETAC 40<sup>th</sup> Annual Conference. Toronto, ON. April 4.

Danovaro R, Bongiorni L, Corinaldesi C, Giovannelli D, Damiani E, Astolfi P, Greci L, Pusceddu A. 2008. Sunscreens cause coral bleaching by promoting viral infections. *Environ Health Perspect*. 116(4):441-7.

Diaz A, Neale RE, Kimlin MG, Jones L, Janda M. 2012. The Children and Sunscreen Study. A Crossover Trial Investigating Children's Sunscreen Application Thickness and the Influence of Age and Dispenser Type. *Arch. Dermatol.* 148(5): 606-612.

Downs CA, Kramarsky-Winter E, Segal R, Fauth J, Knutson S, Bronstein O, Ciner FR, Jeger R, Lichtenfeld Y, Woodley CM, Pennington P, Cadenas K, Kushmaro A, Loya Y. 2016. Toxicopathological Effects of the Sunscreen UV Filter, Oxybenzone (Benzophenone-3), on Coral Planulae and Cultured Primary Cells and Its Environmental Contamination in Hawaii and the U.S. Virgin Islands. *Arch Environ Contam Toxicol*. 70(2):265-88.

He T, Tsui MMP, Tan CJ, Ng KY, Guo FW, Wang LH, Chen TH, Fan TY, Lam PKS, Murphy MB. 2019. Comparative toxicities of four benzophenone ultraviolet filters to two life stages of two coral species. *Sci Total Environ*. 651(Pt 2):2391-2399.

Heerfordt IM, Philipsen PA, Larsen BO, Wulf HC. 2017. Long-term Trend in Sunscreen Use among Beachgoers in Denmark. *Acta Derm Venereol* 2017. 97:1202–1205.

Kais B, Schneider KE, Keiter S, Henn K, Ackermann C, Braunbeck T. .2013. DMSO modifies the permeability of the zebrafish (Danio rerio) chorion-Implications for the fish embryo test (FET). *Aquatic Toxicol* 140-141:229-238.

Klimisch H-J; Andreae M; Tillman U. 1997. A Systematic Approach for Evaluating the Quality if Experimental Toxicological and Ecotoxicological Data. *Reg Tox Pharmacol*. 25:1-5.

Lademann J, Schanzer S, Richter H, Pelchrzim RV, Zastrow L, Golz K, Sterry W. 2004. Sunscreen application at the beach. *J Cosmetic Dermatol*. 3: 62–68.

Maples-Reynolds N, Vamshi R, Williams M. 2019. Environmental Stressors to Coral in the Florida Keys. Report Prepared for Consumer Healthcare Products Association (CHPA). Waterborne Study Number 247.03. Leesburg, VA.

Mitchelmore CL, He K, Gonsior M, Hain E, Heyes A, Clark C, Younger R, Schmitt-Koppline P, Feerick A, Conway A, Blaney L. 2019. Occurrence and distribution of UV-filters and other anthropogenic contaminants in coastal surface water, sediment, and coral tissue from Hawaii. *Sci. Tot. Environ.* 670(20): 398-410.