Dangers of Oxybenzone in Sunscreens on Coral Reefs: Proposed Policy Approaches

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https://doi.org/10.38126/JSPG240106

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Keywords: coral bleaching; reef-safe; chemical ban; green guides

Executive summary: Sunscreen was developed to combat the harmful effects of skin exposure to ultraviolet radiation, but organic UV filters like oxybenzone pose a threat to coral reefs by promoting bleaching incidents, damaging coral DNA, and interfering with coral larvae. Oxybenzone has also been found to cause a wide range of reproductive and developmental harm within other marine organisms, like fish and invertebrates. While there are alternative sunscreens that are less detrimental to coral such as mineral-based products, toxic oxybenzone-based sunscreens are still popular among cosmetic companies and consumers. Scientific findings in the past decade have demonstrated a connection between high concentrations of chemical UV filters and the destruction of marine ecosystems. This knowledge has prompted some governments in coastal regions to pass legislation aiming to limit the use of sunscreens containing these chemicals. These regulations provide beneficial case studies that can be used to develop further effective policies to federally ban these products in the United States. The jurisdictions of Hawaii, the US Virgin Islands, and Key West are model examples of successful implementation of such laws domestically. Based on efforts from such coastal communities, our suggested best practices to eliminate the threat posed by harmful sunscreens are to promote alternative sunscreen use, to define 'reef-safe' within the Federal Trade Commission's Green Guides, and to impose a nationwide ban on oxybenzone. These recommendations provide a comprehensive plan to protect the United States' fragile marine ecosystems.

I. Introduction

Marine and coastal tourism are some of the fastest-growing sectors of the global tourism industry, contributing approximately $143 billion in gross domestic product to the national economy each year (NOAA Office for Coastal Management 2023). Concurrently, the market for suncare products is also rapidly expanding. As of 2023, the global sun care market was valued at $13.6 billion and is projected to grow to $25.3 billion by 2033 (Verghese 2023). As the production and use of sun care products grows, so does the risk of environmental contamination by sunscreen chemicals (Danovaro et al. 2008). Researchers have raised concerns about the ecological effects of ultraviolet (UV) filters on coastal regions and habitats like coral reefs (Danovaro et al. 2008). These UV filters are commonly found in sunscreens and help to protect against the sun's harmful ultraviolet rays; however, they can be released into water from sunscreens and can harm coral reefs (Mitchelmore et al. 2019). Oxybenzone, also known as BP-3 and benzophenone-3, is one of the most common UV filters used in sunscreens and other personal care products (Downs et al. 2022). Found in high concentrations in popular beaches and coastal regions, oxybenzone can cause coral bleaching by promoting viral infections and can inhibit coral reef growth (Danovaro et al. 2008, Downs et al. 2016). Exposure to oxybenzone can also

lead to changes in fish feeding and swimming behaviors (Barone et al. 2019), along with the possibility of disrupting endocrine systems (Wang et al. 2016). Additionally, oxybenzone is a photo-toxicant, meaning its effects are exacerbated by sunlight (Downs et al. 2016). This poses further implications for coastal nations with local coral reef populations, which require warm water and ample sunlight to thrive.

Between 6,000 and 14,000 tons of sunscreen, many of which contain between 1-10% oxybenzone, are released into coral reef areas each year. This places at least 10% of the global reefs and 40% of coastal coral reefs at exposure risk (Wood 2018). Coral reefs are one of the most biodiverse ecosystems and a critical part of aquatic ecosystems, sustaining approximately one-fourth of all marine species in addition to protecting coastlines from erosion by absorbing wave energy (Miller et al. 2021). They also provide a multitude of economic benefits by providing food, jobs, recreation, and natural materials that can be used as building materials or medicines (Miller et al. 2021). We argue that proper government intervention in the form of a federal ban on oxybenzone is necessary to mitigate the effects of UV filter pollution and preserve coral ecosystems worldwide. In response to the growing evidence of the environmental harm caused by UV filters like oxybenzone, three primary responses have emerged: (1) the passage of UV filter bans in multiple coastal nations, (2) define "reef safe" in the Green Guides, and (3) an increase in marketing of "reef safe" sunscreens such as mineral-based alternative products.

II. Ecological impacts of oxybenzone

As previously mentioned, oxybenzone causes a wide range of reproductive and early developmental harm to fish and invertebrates, including endocrine disruption, genotoxicity, and cell death (Downs et al. 2016). Oxybenzone can additionally cause coral bleaching, which occurs after a coral experiences stress such as abnormally high temperatures. Oxybenzone exposure lowers the temperature at which corals will bleach, resulting in the expulsion of mutualistic algae from coral tissue, which can lead to coral death (Vuckovic et al. 2022). Coastal nations are already feeling the effects of global warming through threats to local reef ecosystems such as coral bleaching. Increased anthropogenic activity introduces additional oxybenzone into coastal ecosystems, imposing further danger.

Researchers in the US Virgin Islands monitored multiple coastal sites with coral populations on the island of St. John for a 5-year period from 2005-2010 to determine if there was a link between increased concentrations of oxybenzone in the seawater and coral reef health (Downs et al. 2016). In Trunk Bay, an incredibly popular beach with high levels of recreational activity, samples showed oxybenzone concentrations of up to 1.4 parts per million (ppm) mg per liter (mg/L) of seawater, which is higher than the lethal concentration for coral at 50% (LC50) which ranges from 0.042 to 2.9 ppm mg/L (Downs et al. 2016). This number varies depending on the type of coral, the coral's stage of development, and the amount of sunlight since oxybenzone is a photo-toxicant (Downs et al. 2016). The lower range of oxybenzone concentration tolerance represents the LC50 for coral cells exposed to light (Downs et al. 2016). Because of this, even low levels of exposure to oxybenzone at this stage of development can limit coral growth. As a result, scientists in Trunk Bay found no substantial settlement of coral larvae, survival of juvenile corals, or regeneration of adult tissue in induced lesions over a 5-year period (Downs et al. 2016). These findings were compared to a thriving coral community with significantly lower anthropogenic activity near Caneel Bay, where samples showed very low, undetectable levels of oxybenzone (Downs et al. 2016).

Studies in other coastal regions reach similar findings. Researchers in Hanauma Bay, Hawaii, found that high levels of oxybenzone concentrations posed a serious threat to the local coral reef ecosystem, and identified swimmers as one of the principal sources of the contaminant (Downs et al. 2022). Additionally in Maya Bay, Thailand, extensive ecological delay was linked to high levels of recreational activity (thousands of tourists visit the bay every day), resulting in the temporary closure of the bay in 2018 to allow the marine ecosystem to recover (Koh & Fakfare 2019).

III. Existing restrictions and chemical bans

In response to the degradation of local marine habitat health, several coastal nations and regions have passed laws limiting the number of beach

visitors and restricting or banning the sale of oxybenzone-containing products. Research on organic UV filter contamination has significantly contributed to the establishment of stricter legislation and bans in the US Virgin Islands, Hawaii, Palau, Mexico, Bonaire, and Thailand (Table 1). In Maya Bay, the Thai government restricted all recreational access to the area beginning in 2018 and ending in early 2022. During this period, local marine biologists worked to restore the population of aquatic organisms, such as coral, and reported noticeable improvement as a result of this measure (Cripps 2022). In the US Virgin Islands under Act No. 8185, the retail sale, distribution, and importation of topical sunscreen products containing chemicals like oxybenzone and octocrylene, another UV filter, is strictly prohibited. Violations of this law warrant immediate confiscation of the illegal products, a $1,000 fine for the first offense, and a $2,000 citation for each subsequent offense. For example, in July of 2023, the Department of Consumer and Licensing Affairs confiscated large amounts of illegal sunscreens from a Walgreens in St. Thomas after receiving a complaint less than forty-eight hours prior (Carlson 2023).

Opposition groups argue that there is a lack of adequate scientific evidence to support the claims that these chemicals harm corals (Mitchelmore et al. 2019). However, oxybenzone has been found to cause coral damage, including bleaching, DNA damage, and growth abnormalities in multiple studies (Downs et al. 2016, Downs et al. 2022). The bans have received support from environmental groups, public health advocates, and lawmakers who believe that restrictions are essential to the preservation of marine ecosystems. There is no definitive answer as to what ingredients are safe, but an estimated 14,000 tons of sunscreen reach coral reefs via ocean currents annually (Matsumoto 2019). Adopting the precautionary principle, to avoid causing harm especially when alternatives exist, banning oxybenzone will only have positive impacts on marine ecosystems.

IV. Recommendations and further steps

i. Oxybenzone ban

We suggest a federal ban on oxybenzone due to the success of state level legislations. In 2016, scientific panels held at the International Coral Reef Symposium (ICRS) and the International Union for the Conservation for Nature (IUCN) in Honolulu showed a consensus that oxybenzone is toxic to corals and recommended a ban on sunscreen products that contain the chemical (Day 2018). A federal ban is preferable to a state ban as passing legislation in multiple coastal states would be difficult. A federal law would also prevent residents of states without existing oxybenzone bans from bringing and using products with BP-3 in states with existing oxybenzone bans such as Hawaii.

Additionally, residents of landlocked states can still suffer from the possible negative health impacts posed by the use of sunscreen containing oxybenzone because the chemical is a hormone disruptor and can affect estrogen production in women and testosterone production in men. Inversely, coastal states could still be affected by landlocked states through oxybenzone entering their waterways from showers and even toilets as oxybenzone can be spread through urine (Downs 2016).

Table 1: Jurisdictions with sunscreen laws that ban compounds harmful to coral.

Location	Name of Law	Description of Law
US Virgin Islands (06-25-2019)	Act No. 8185	• Bans distribution and use of products containing oxybenzone and octinoxate ○ Fine of $1,000 for 1st offense and $2,000 for subsequent offenses • All persons in possession of oxybenzone, octocrylene, or octinoxate must dispose of them to the V.I. Waste Management waste collection system process before March 30, 2020

		• Unlawful to place new orders for any sunscreen product containing these chemicals

Hawaii (07-01-2020)	Act 104, Session Laws of Hawaii 2018	• Bans use and sale of oxybenzone and octinoxate products without a prescription
		• 2-year pilot program to install mineral-based alternative sunscreen dispensers at Hanauma Bay Beach
		  ○ Dispensers include informational signage about the harmful effects of oxybenzone and octinoxate on corals
		  ○ Funded by general revenues of the State of Hawaii

Palau (01-01-2021)	Responsible Tourism Education Act of 2018: Sunscreen Regulations	• Bans 30 reef-toxic chemicals
		• Prohibits international arrival with reef-toxic sunscreens, manufacturing or sale of reef-toxic sunscreens
		• Proper disposal of confiscated or surrendered reef-toxic sunscreen
		• Each violation results in a $100 per consumer unit fine
		  ○ Sale: $5,000
		  ○ Distribution: $5,000
		  ○ Manufacture: $10,000
		  ○ Import: $10,000

Mexico: Xel-Ha & Xcaret marine parks (01-01-2021)	Mexican Caribbean Initiative	• Ban of non-biodegradable chemical sunscreens
Bonaire (01-01-2021)	Bonaire National Marine Park Sunscreen Regulation	• Prohibits sale, distribution, and use of sunscreens containing oxybenzone, octinoxate, and octocrylene
Thailand (07-03-2021)	Thailand Marine National Parks' sunscreen ban	• Bans oxybenzone, octinoxate, 4-Methylbenzylid Camphor, and Butylparaben ○ Fined up to 100,000 Baht ($2935)

We recommend that a federal ban on oxybenzone is adopted, modeled closely after Hawaii's legislation, known as Act 104 (Hawaii Senate Bill 2571/Act 104, 2018), as their law was the first statewide ban on sunscreens and set the standard for similar UV filter bans in coastal nations (Day 2018). Act 104 specifically outlines the impacts of oxybenzone on Hawaii's natural resources, states explicitly that the sale and distribution of personal care products containing BP-3 without a medically-licensed prescription are unlawful, and provides clear definitions of "oxybenzone" and "SPF sunscreen protection personal care product". A federal ban must contain similar guidelines as this act. The Hawaii law also provided a 2.5 year period to phase out the sale and distribution of sunscreens with oxybenzone. However, this phaseout period could be extended to accommodate a national ban. While Hawaii's Act 104 bans both oxybenzone and octinoxate, another UV filter, we recommend that the federal ban initially only target oxybenzone. As the most researched sunscreen chemical, numerous

studies have demonstrated the dangers of oxybenzone, justifying a federal ban. All the legislation mentioned includes restrictions on oxybenzone, emphasizing a widespread concern for oxybenzone specifically. If the federal ban is successful in increasing the survival rate of corals, increased research to better understand how UV filters other than oxybenzone affect human and environmental health are needed. In turn, this research can be used to justify an expansion of this ban to include other UV filters.

In Florida, State Bill 172 was passed and took effect in 2021 to prevent bans on chemicals, like oxybenzone within cosmetics (Florida State Legislature 2020). This bill was strongly supported by corporate interests attempting to prevent changes to product ingredients (Duong, 2021) and it overturned a previous ban in Key West that prevented the sale of oxybenzone and octinoxate. Possible state laws like these outline the necessity of creating a nationwide ban to streamline efforts to protect coral reefs.

ii. Green Guides and defining reef-safe

The integration of the term 'reef-safe' into the Federal Trade Commission's (FTC) Green Guides will provide supplemental educational and legislative support towards a nationwide ban. The FTC's 2012 Green Guides outline that broad claims about general environmental benefits using language such as "green" and "eco-friendly" should be avoided due to a lack of explicit definitions (Federal Trade Commission 2012). Terms such as 'degradable', 'free-of', and 'recyclable' are defined within the guides and include limitations and suggested regulations for each word (87 F.R. 77766). But, there is no mention of 'reef-safe' within these guides. The guides do mention 'ozone-friendly,' which is similar in concept to 'reef-safe,' and could be used as a model for 'reef-safe' to be added within the Green Guides. Changing the guides to include new definitions and regulations is not unprecedented as it has undergone changes in 1996, 1998, and 2012 (Rotman 2020).

However, there are barriers to incorporating 'reef-safe' into the Green Guides. Currently, there is no federally recognized definition of 'reef-safe' nor an established standardized toxicity test for coral reefs that can create clear limits for the type and concentrations of chemicals used in sunscreens. For instance, in a 2018 report written by DME Slijkerman and M Keur, due to gaps in toxicity research and testing, zinc-based UV filters, a typical chemical sunscreen alternative, were observed as potentially harmful to certain coral reefs. (Slijjerman 2019, 48). With additional toxicity testing, this report estimates a reduction in environmental risk. Then, out of fifty-two sunscreens labeled as 'reef-safe' by their manufacturers, twenty-three contained Reef Toxic Ingredients as specified by the National Oceanic and Atmospheric Administration (NOAA), and only two of those sunscreens contain oxybenzone (Tsatalis 2020). Therefore, these studies reveal the need for research towards a standardized test, whether utilizing the NOAA-specified Reef Toxic Ingredients or an alternative criteria, to assist in outlining which chemicals and concentrations should be included in the definition of 'reef-safe' (Slijkerman 2019).

Slijkerman's recognition of a lack of sufficient risk assessments of UV filters supported by Tsatalis's report highlights the limits of our current information regarding the toxicity of various sunscreen filters. To amend this, a study by Miller (2021) recommends a standardized toxicity test under the umbrella of the International Standards for Organization (ISO) or the Organization for Economic Cooperation and Development (OECD) as mandatory to allow scientifically sound tests, comparable assessments of substances, and mutually regulatory acceptances of test results. These tests would account for product concentrations, amount applied, release rates, and other similar factors (Miller 2021). Then, further studies of the effects of UV filters on the acute and chronic toxicity for different stages of coral must occur. The standardization process is expected to take several years, but is possible, as other similar standardized tests like the OECD test guidelines for freshwater organisms exist (Miller 2021).

However, it is important to recognize that the Green Guides are not enforceable and businesses or legislation can divert from these guides without legal consequence (Bergeson 2011). Even with the addition of 'reef-safe' to the guides, businesses can continue to misuse the phrase. This forces the responsibility onto the consumer and requires them to be knowledgeable about oxybenzone's effect on

coral, which is an unreasonable expectation and further promotes a lack of accountability within corporations.

This issue of unenforceable sustainable management has been faced by the forestry industry as well and has been addressed through third-party sustainable forestry certifications, such as the Scientific Certification System or the Forest Stewardship Council, that corporations can participate in. Similarly, these certifications arose to fill the gap between the lack of a federal or international agreement or bans on sustainable forestry practices (Bernstein 2004). The third-party certification's purpose is to educate and ensure customers that their products have been derived from sustainably managed forests (Bernstein 2004). Similarly, the label of 'reef-safe' on sunscreen products will inform customers that the product is a safer alternative to comparatively more toxic UV filters. While the label 'reef-safe' is not a certification, this comparison provides insight on ways to address a lack of federal regulation and enforcement.

To further address the gap within the Green Guide's enforcement, we suggest the establishment of additional incentives in the form of tax credits or grants for sunscreen manufacturers who properly advertise 'reef-safe' within their products. Tax incentives for green initiatives have been effectively utilized nationwide to correct market failures within industries related to energy-efficiency and clean fuel (International Revenue Service 2024). With similar incentives, companies can be motivated to integrate the Green Guides into their products and properly label them 'reef-safe'.

Without a definition of 'reef-safe' there will be a continued misuse of the word and a public misunderstanding of the toxicity of UV filters. Integrating 'reef-safe' into the Green Guides can provide an achievable federal recognition of the dangers of oxybenzone, and potentially other UV filters, as has been done with 'ozone-friendly'. For this to be established, a standard toxicity test must be created to provide a basis for the definition. Even with the unenforceable nature of the Guides, this integration can be beneficial for consumers to ensure they are purchasing a 'reef safe' product. Future policies can utilize this definition for the development of more progressive regulations on toxic UV filters, like a federal oxybenzone ban. Combined with state bans, like those in Hawaii and the US Virgin Islands, this can create more support for a federal ban. Further, 'reef-safe' within the guides can serve as a way to educate and raise awareness of the dangers of certain sunscreen chemical ingredients towards coral and other aquatic life.

iii. Encourage alternative sunscreen and ways to shield from UV rays

With a ban on oxybenzone, alternative sunscreens and ways to shield from the sun must be promoted. Mineral based sunscreens refer to products that contain zinc oxide and/or titanium dioxide that physically shield the skin from UV rays (Engler 2022). These sunscreens contain ingredients that are less harmful to marine environments in comparison to some organic UV filters, reduce skin irritation, and better protect against UV radiation (Table 2). These mineral based sunscreens can be used as an alternative to oxybenzone. While alternative sunscreens are lower in toxicity, potential negative impacts on aquatic life may remain. Therefore, reducing the release of sunscreen to aquatic habitats must also be emphasized through alternatives to sunscreen application. The benefits of photoprotective clothing such as rash guards, hats, and sunglasses must be conveyed to the public (Miller 2021).

Table 2: Pros and cons of mineral-based sunscreens.

Topic	Pros	Cons
Environmental Impacts	Contain natural ingredients less harmful to the marine life (Downs et al. 2016)	Micronized zinc could be ingested by marine life (Engler 2022)
Skin Reaction/ Aesthetics	Safer for sensitive skin because they are less likely to cause skin irritation or	Can leave a white residue on the skin, which is especially aesthetically

	allergic reactions (McCallum 2022; Engler 2022)	problematic for individuals with darker skin tones (Engler 2022)
Skin Protection	Provide better and longer lasting UV radiation protection (Engler 2022). All mineral sunscreens are broad spectrum (McCallum 2022)	Tend to have a thicker consistency, making them difficult to apply evenly, resulting in patches of unprotected skin (Engler 2022)
Active Ingredients	Zinc oxide and titanium dioxide (active ingredients in mineral sunscreens) are recognized as safe and effective by the FDA (Matta et al. 2019).	Potential to accumulate in sediment and harm other marine organisms (Juliano 2017).

V. Conclusions

Oxybenzone's negative effects on coral reefs have been demonstrated by numerous studies and are difficult to ignore. What remains is to determine the best policy approach. Using mineral-based sunscreens can be advantageous when assessing alternatives to oxybenzone due to the lower toxicity and better UV protection. Since these alternatives are already on the market, replacing sunscreens containing oxybenzone with mineral-based sunscreens is realistic but opposed by companies that produce sunscreen containing oxybenzone. A step the FTC is amending the Green Guides to include a "reef-safe" provision and a standardized toxicity test to prevent mislabeling sunscreens. This will not only help to better inform the public on the effects of oxybenzone, but also provide a base definition of 'reef-safe' for a possible ban on oxybenzone and future policies. This can be further supplemented by educational programming on alternative sunscreens and ways to shield from UV rays. Establishing a federal ban as opposed to state bans will have a more significant impact on coral reefs and protect vulnerable coastal regions from oxybenzone entering waterways from other states. Through effective policies and regulations, such as the ones suggested, coral reefs and marine environments can be conserved with sustained, long term protection.

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Acknowledgments
We would like to thank Dr. Patrick Shirey for his continued assistance and support through the writing process and the University of Pittsburgh Environmental Law and Policy course for providing us the platform to create and submit this manuscript.