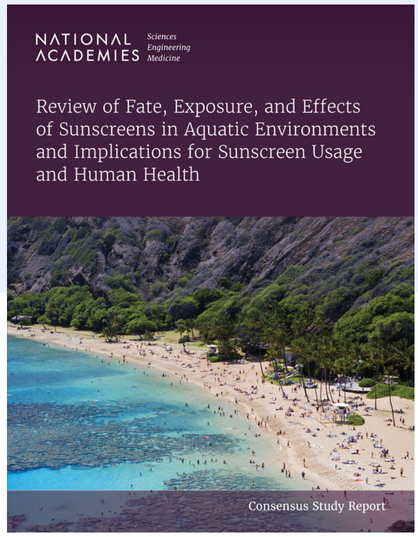
NATIONAL ACADEMIES *Sciences Engineering Medicine*

Consensus Study Report
Highlights

Review of Fate, Exposure, and Effects of Sunscreens in Aquatic Environments and Implications for Sunscreen Usage and Human Health



UV (ultraviolet) filters, which are the active ingredients in sunscreens that reduce the amount of UV radiation reaching the skin, have been detected in water, sediments, and marine life in both saltwater and freshwater aquatic environments. Their presence, while itself not indicative of environmental harm, has led to a rapid increase in research on their potential environmental impact. However, the use of sunscreens is a critical tool for helping people reduce their risk of sunburn and skin cancer and slow the pace of skin aging. There are currently 17 UV filters (see Box 1) that can be found in sunscreen products marketed in the United States, though not all are in common use.

It is challenging to determine whether and under what conditions individual or mixtures of UV filters are a risk to organisms and ecosystems—either alone or in combination with other environmental stressors—and where these conditions might occur. An ecological risk assessment (ERA) is a process that can help identify the particular exposure setting(s) in which UV filters could be the cause of ecological impacts.

This report reviews the state of science on the sources and inputs, fate, exposure, and effects of UV filters in aquatic environments, and the availability and applicability of data for conducting ERAs. It also reviews the scientific literature on the efficacy of sunscreen in preventing UV damage to human skin, the state of knowledge on potential human behavior changes, and the potential health impacts in terms of skin cancer prevention resulting from changes in sunscreen usage.

BOX 1
UV FILTERS CURRENTLY MARKETED IN THE UNITED STATES, 2022

UV filters in sunscreens absorb, reflect, and/or scatter the sun's rays to reduce the amount of UV radiation that reaches the skin. UV filters are also used in a variety of other products, including cosmetics, hair and skin care products, insect repellents, and other consumer and industrial applications.

Organic UV Filters		Inorganic UV Filters
Aminobenzoic acid	Meradimate	Titanium dioxide (TiO_2)
Avobenzone	Octinoxate	Zinc oxide (ZnO)
Cinoxate	Octisalate	
Dioxybenzone	Octocrylene	
Ecamsule	Oxybenzone	
Ensulizole	Padimate O	
Homosalate	Sulisobenzone	
	Trolamine salicylate	

INPUTS OF UV FILTERS INTO THE ENVIRONMENT

There are two ways that UV filters can get into water bodies. The first is direct release into the water, particularly when sunscreens rinse off of people during swimming or other aquatic recreation. Highly variable concentrations of some UV filters have been correlated with the time, location, and intensity of recreational activity.

UV filters can also enter aquatic environments through stormwater runoff (though very little is known about this) and wastewater. The extent of UV filter removal at centralized wastewater treatment plants depends on the UV filter's affinity for association (e.g., biosorption) to bacterial sewage solids and susceptibility to biodegradation (breakdown by microorganisms). Homosalate, meradimate, octocrylene, octinoxate, octisalate, and padimate O, titanium dioxide, and zinc oxide are most likely to be highly removed in wastewater treatment.

Once released to the environment, UV filters can partition into different environmental compartments (e.g., air, water, sediment, organisms) depending on their physical and chemical properties. With the notable exceptions of ensulizole, aminobenzoic acid, trolamine salicylate, and sulisobenzone, the organic UV filters are generally hydrophobic (tending to repel or not mix with water) and thus would be expected to partition into particles and sediments. Oxybenzone is moderately water soluble. TiO_2 and ZnO aggregate with other particles in the water column and accumulate in river, lake, or estuary sediments. ZnO may dissolve into ions, depending on water conditions.

CONCENTRATIONS IN WATER, SEDIMENTS, AND BIOTA

Available data on UV filter concentrations in water and sediments reveals general temporal and spatial patterns: the highest measured concentrations of most UV filters occur in shallow waters, within or near recreational areas (e.g., swimming beaches), and during the day. For several organic UV filters—oxybenzone, octocrylene, homosalate, avobenzone, and octinoxate—the available data show that the highest measured environmental concentrations in water are in the range of 1 to 10 µg/L, though most measurements for these and all measurements for other organic UV filters are below 1 µg/L. Except for octocrylene and octinoxate, which have maximum recorded concentration values between 0.1 and 2.4 µg/g dry weight, all other UV filters exhibit maximum recorded concentrations in sediments below 0.1 µg/g dry weight.

UV filters have been detected in aquatic organisms. UV filters exhibit a range of bioaccumulation potentials, driven primarily by the lipophilicity (tendency to mix with fats, oils, and lipids) of the compound and the degree of metabolism by biota. Avobenzone, octocrylene, octinoxate, oxybenzone, homosalate, padimate O, and titanium dioxide have a low to moderate bioaccumulation potential.

EFFECTS OF UV FILTERS IN AQUATIC ENVIRONMENTS

Laboratory toxicity tests are most widely used to provide the effects data required for ERAs. There are more toxicity studies of acute (shorter duration) exposures than there are for chronic (longer duration) exposures. However, chronic toxicity studies are critically important, especially given the number of UV filters that would be expected to be found at relatively low dissolved concentrations in the environment.

Laboratory observations show that, in high enough concentrations, some UV filters can be toxic to algal, invertebrate, and fish species (see Figure 1). However, studies are lacking across a diversity of species, particularly marine species, and are challenged by the absence of standard test methods for many species of importance, such as corals.

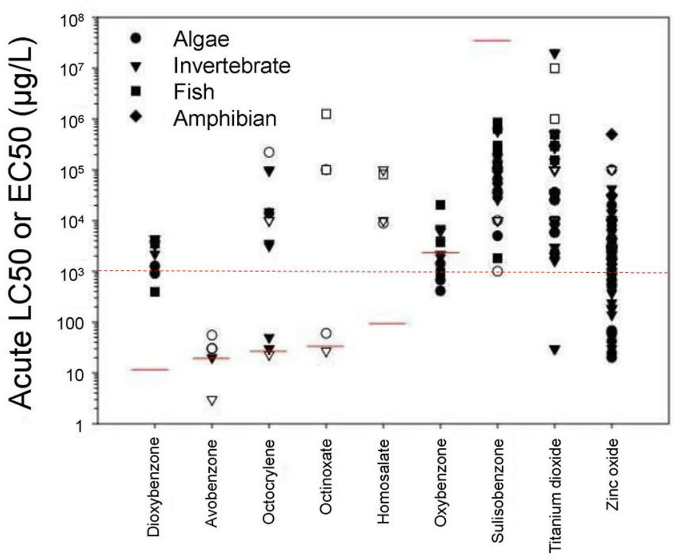


FIGURE 1 Representative acute toxicity data for select UV filters.
NOTES: 1,000 µg/L is used as a threshold for comparison across UV filters (red dashed line); toxicity at lower concentrations indicates a more toxic UV filter. However, due to the low water solubility of some UV filters (red solid lines), the potential environmental concentrations could be below toxic levels. LC/EC50 results that were unbounded (not < or >) values are displayed with closed (black) symbols whereas greater than (>) values are displayed as open (white) symbols. LC50 = Lethal concentration for 50 percent of the test population; EC50 = Concentration of nonlethal effects on 50 percent of the test population that are effectively equivalent to mortality.

SUNSCREEN EFFICACY AND USE FOR HUMAN HEALTH

Exposure to UV radiation causes sunburn and photoaging and is a risk factor for the development of skin cancer. Large randomized controlled trials and longitudinal observational studies have demonstrated that consistent use of broad-spectrum, SPF 30+ sunscreen when outdoors reduces the risk of developing skin cancer, photoaging, and sunburn, though research has been focused on populations with fair skin. Sunscreen use is part of a recommended regimen of photoprotection that also includes the use of protective clothing, sun avoidance, and shade-seeking behaviors. However, only about one-third of the U.S. population uses sunscreen regularly, though use is higher during outdoor activities and at the beach (between 70 and 80 percent). The main drivers of sunscreen preferences are the perceived efficacy and cosmetic appeal.

Restrictions on certain UV filters may have negative impacts on human health if they lead to reduced sunscreen usage. The report describes potential alternative scenarios to current use and choice of sunscreens:

- Scenarios likely to lead to negative effects on health:
  - Decreased use of sunscreen with no change to other sun protective behaviors
  - Decreased use of sunscreen with suboptimal increases in other sun protective behaviors
  - Use of alternative sun protection products with UV filters that do not meet U.S. Food and Drug Administration (FDA) standards
- Scenarios likely to lead to no or minimal effects on health:
  - Decreased use of sunscreen with optimal practice of other sun protective behaviors
  - Obtaining sunscreens with restricted ingredients from elsewhere
  - Switching to alternate formulations
- Scenario likely to lead to positive effects on health:
  - Increased use of sunscreen

The ability to purchase broad-spectrum, SPF 30+ sunscreen that people will actually use, is a key determinant of health outcomes. Educational and motivational campaigns that encourage the use of sunscreen at recommended levels along with other photoprotective behaviors where feasible—along with other supports such as public shade structures—may mitigate these harms.

NEED FOR AN ENVIRONMENTAL RISK ASSESSMENT ON ONGOING RESEARCH

Given the evidence of local exposures of aquatic organisms to UV filters in U.S. aquatic ecosystems, potentially including endangered species, and experimentally demonstrated potential for environmental impact, **the U.S. Environmental Protection Agency (EPA) should conduct an ecological risk assessment for all currently marketed UV filters and any new ones that become available.** The results of the ERA should be shared with FDA for its considerations of the environment in its oversight of UV filters.

While conducting an ERA in the near term is imperative, future assessments will be improved by increased data collection. Knowledge gaps have been identified in each chapter of the report. **The EPA, partner agencies (e.g., Centers for Disease Control and Prevention, U.S. Department of the Interior, FDA, National Institutes of Health, National Oceanic and Atmospheric Administration, National Science Foundation), and sunscreen formulators and UV filter manufacturers should conduct, fund or support, and share research and data on sources, fate processes, environmental concentrations, bioaccumulation studies, modes of action, and ecological and toxicity testing for UV filters alone and as part of sunscreen formulations. Additionally, epidemiological risk modeling and behavioral studies related to sunscreen usage should be conducted to better understand human health outcomes from changing availability and usage.**

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FOR MORE INFORMATION
This Consensus Study Report Highlights was prepared by the National Academies based on the Consensus Study Report *Review of Fate, Exposure, and Effects of Sunscreens in Aquatic Environments and Implications for Sunscreen Usage and Human Health* **(2022).**

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