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A review of inorganic UV filters zinc oxide and titanium dioxide.

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Author information

Abstract

Photoprotection has become integral in the prevention of keratinocyte cancer and photoaging. Organic ultraviolet (UV) filters such as oxybenzone and octinoxate have become controversial due to their potential impact on the environmental and their potential human health risks. As such, inorganic UV filters, zinc oxide (ZnO) and titanium dioxide (TiO_2), have become paramount in discussions about photoprotection. ZnO and TiO_2 are used in sunscreens as nanoparticles, which denotes a size <100 nm. The smaller size of these mineral particles increases their cosmetic acceptability by users as they are much less visible after application. ZnO has a broad UVA-UVB absorption curve, while TiO_2 provides better UVB protection. Overall, the human health risks with inorganic filters are extremely low given a lack of percutaneous absorption; however, there is potential risk when exposed via inhalation, prompting recommendations against spray **sunscreen** products with nanoparticles. At this time, the known risk to the environment is low though the risk stratification may evolve with increasing usage of these filters and higher environmental concentrations. The continued practice of photoprotection is critical. The public should be counseled to seek shade, use photoprotective clothing including hats and glasses in addition to sunscreens on sun-exposed skin. For those concerned about emerging evidence of environmental impact of organic UV filters, based on current evidence, ZnO and TiO_2 -containing sunscreens are safe alternatives.

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The Guardian

Healthy holidays and a sunscreen rethink: top five travel trends for 2019

Rising eco-awareness, wellness breaks and a farewell to passports ... we look at changes in the world of travel for the year ahead

Fri 4 Jan 2019 05.47 EST

Healthy holidays become the new norm

Last October, Club 18-30 holidays staggered off into the sunset, aged 50. To the relief of Mediterranean resorts that had spent decades dealing with the carnage caused by epic drinking challenges, it appears that buckets of warm sangria - or worse - have lost their appeal. We have entered the era of the healthy holiday, driven by young people who want to be sober enough to take a flattering selfie. The rise of 'ego travel' was cited by Thomas Cook when it retired the Club 18-30 brand, turning its focus on its Casa Cook and Cook's Club brands, design-conscious hotels with gyms, tasting menus, upmarket cocktails and yoga.

But the staggering rise in wellness tourism - now worth $639bn globally and growing more than twice as fast as general tourism, according to the Association of Travel Agent's 2019 Travel Trends

report - isn't just down to young people. Wellness resorts are targeting all ages, with holidays for every stage of life, from fitness stag dos to baby moons, mumcations and menopause retreats.

In the summer, Longevity Health & Wellness Hotel opens on the Algarve with a raft of fitness activities, a medical spa and meals that cater for all sorts of diets. It follows in the footsteps of sports resort FeelViana Hotel, on the coast of Portugal, north of Porto. In Italy, Lefay Resort & Spa's second resort, Dolomiti, also opening in summer, promises a 24-hour fitness centre and a huge east-meets-west spa.

But it's not just specialist resorts and hotels catering for the demand. Holiday companies such as G Adventures and river cruise operator Uniworld are introducing trips with yoga and meditation sessions and healthy food.
Isabel Choat

Single-use plastic will become as antisocial as smoking

Photograph: Stian Lysberg Solum/EPA

Last year was the year the travel industry joined in with the general stand against single-use plastic, with tour operators and hotels clamouring to announce bans on plastic straws or eliminating single-use plastic altogether. Some went further, introducing trips that actively involve holidaymakers in litter clearing and beach clean-ups. This will continue in 2019 as a commitment to tackling the global plastics crisis goes mainstream and consumer pressure grows.

Over a third (36%) of people would opt for one travel business over another if it has a better environmental record - up from 23% in 2014, says the Abta report. Last November, Thomas Cook announced its pledge to reduce plastic in its supply chain - though without saying by how much. Global hotel chain Melia International, which has 370 hotels in 40 countries, will have eliminated all plastics by summer 2019 (in 2017 alone it got through 22 million plastic bottles).

In 2019 regulations banning all single-use plastics will come into effect in several destinations, including the Caribbean islands of Aruba and Grenada, the Galapagos and the Californian city of Santa Monica. Single-use plastic is becoming as anti-social as smoking and it would be a brave, or stupid, travel business that didn't join the fight to help reduce the amount clogging up the planet. Consumers will have to work out which ones are genuinely making a difference and which are just paying lip-service.
IC

Rethink your sunscreen

Photograph: Rex Features

While sunscreens are crucial for UV protection, recent research indicates that once certain chemical ingredients, particularly oxybenzone and octinoxate, enter the water, they become harmful to humans and nature, and have been implicated in coral reef bleaching.

In a world first, last May Hawaii passed legislation that will ban the sale and distribution of any non-prescription sunscreen containing these chemicals (found in 78% of the most popular brands) from 2021. The Caribbean island of Bonaire followed in the same month. The most comprehensive ban so far is in the small Pacific island nation of Palau, which is to ban the buying, selling, importing or manufacturing of sunscreen and skincare products that contain these chemicals and eight additional ones, from 2020.

The trend will continue in 2019. More than 30 countries and 19 US states are currently discussing the issue or have bills progressing. Expect more consumer pressure to make manufacturers review and improve their products, and provide clearer labelling.
Dr Catherine Wilson, freelance writer specialising in sustainability, tourism and technology

Instabans will spread

Photograph: Robert Hoetink/Alamy

Instagram has transformed travel. Today, 61% of 18-24-year-olds want to share "beautiful or important" holiday experiences online (weswap.com). Aware of the power of the 'gram, tourist boards, hotels and resorts now pay photographers with large followings to post shots from their hotel or poolside. In doing so they've helped the canniest 'grammers to forge lucrative careers.

The rest of the travel industry has scrambled to get in on the act, slavishly promoting "Instagrammable" trips and places at every opportunity.

But the backlash has started, and will be picking up pace in 2019. Spoof accounts such as "youdidnotsleepthere", which lampoons adventure travel feeds showing people camping in amazing locations, have been around for a while, but Instagram is now being blamed for more serious offences than encouraging hipster road trips. "Instagram deaths", caused by people trying to get the perfect shot in precarious locations, and unsustainble crowds, lured to beauty spots by photos seen on the site, are leading some destinations to take action.

In autumn 2018, Vienna launched an anti-social media campaign with the slogan "Welcome to Vienna. Not #Vienna" while one Bali resort hit the headlines for banning smartphones by its pool.

For every ban, there are hundreds of other destinations desperately promoting themselves as Instagram-friendly, but for those of you who have resolved to scroll less this year, the options for a digital detox are on the rise.
IC

Your face will be your passport

A facial recognition system at Washington Dulles airport.
Photograph: Jim Watson/AFP/Getty Images

Brexiteers excited about the return of the good old blue British passport will find that their new document's days are numbered. New facial recognition technology is already being trialled, with Heathrow airport planning a full-scale rollout of this summer, introducing biometric technology that uses facial recognition at check-in, bag drops, security lanes and boarding gates, which it claims will reduce time spent at airports by a third. Heathrown says this will be the largest deployment of biometrically enabled products in the world, but it's not alone in planning for a paperless future: 63% of UK and international airports are planning to invest in biometric ID management by 2020 (source: sita.aero). In Singapore, Changi airport's new Terminal 4 makes extensive use of biometrics and the Australian government is funding its introduction across that country's airports. With global air passenger numbers set to double in the next 20 years, anything to smooth the worst part of international travel - the airport experience - will to be welcomed by many, though experts have also raised concerns about data security.
Ryan Ghee of the Future Travel Experience

FLORIDA DEPARTMENT OF
ENVIRONMENTAL PROTECTION

The South Florida Reef Ambassador Initiative -- Become a Coral Champion!

The South Florida Reef Ambassador Initiative – Become a Coral Champion!

The Florida Reef Tract stretches almost 350 miles from the Dry Tortugas National Park to the St. Lucie Inlet along the coast of 5 counties: Monroe, Miami-Dade, Broward, Palm Beach and Martin. Home to over forty species of coral and hundreds of species of fish, with many species of turtles and sharks making an appearance as well.

While ecologically important, the counties also recognize the vast economic benefit from these reefs. Each year alone, reefs contribute **6.4 billion dollars** and **70,000 jobs** annually to our local communities! The proximity of these reefs means that the residents of one of the world's most densely populated coastal communities are dependent on these reefs not only for their economic input, but also the protection they offer our beaches and homes from storms and hurricanes!

Despite their importance, there are localized impacts that threaten the health of our local reefs. To address these impacts, scientists and experts from across the globe are working together to increase our understanding and prevent further damage. However, to successfully defend our reefs they will need the help from everyone. With this in mind, the 5 counties in southeast Florida have become Reef Ambassadors, and developed a regional program to help tourists, boaters and divers understand how they can help conserve and protect our local reefs! By following the Reef Ambassador's simple set of easy to remember rules, you too can help defend the reefs and become a **Coral Champion**!

For general tips to become a **Coral Champion**, please read below:

Reef Ambassador Advice: Boating

- Absolutely never drop an anchor on the reef. This is illegal under Florida's Coral Reef Protection Act (CRPA), and could be associated with heavy fines. Find a nice sandy bottom, drop your anchor, and float out back across the reef. If you are having trouble locating sandy bottom, check out our free phone application.

- If you cannot find sand, you may also make use of free public mooring buoys all over the southeast region! Click here for buoy location information.
- Boats can be disease vectors and transplant potentially harmful exotic species. Wash your boat as thoroughly as possible after use, including the bilge, before moving from one area to the next.
- Fuel up and add oil in calm areas to avoid spills. Avoid overflowing your fuel tanks and oil receptacles.
- Keep a sharp eye out for manatees and sunning sea turtles!

Reef Ambassador Advice: Diving

- Avoid sunscreens with Oxybenzone and Avobenzone. The -benzones are compounds that are lethal to coral reproduction in very small amounts. Many common sunscreens contain between 1-10% Oxybenzone or Avobenzone, so please check the ingredients list.
    - Note: If you cannot find any sunscreen without Oxybenzone or Avobenzone, you should still wear sunscreen to protect yourself from harmful UV rays.
- To prevent the spread of coral disease, it is **recommended that you** clean your gear when moving between dive sites. While on board your vessel, disinfect your gear in a water bath rinse, using any non-ionic detergent or soap. Once returning to shore, use a diluted bleach wash to quickly and effectively remove any disease trace. Please note that this disease poses no threat to human health, the cleaning of dive gear serves only to prevent the spread of the disease.
- Buoyancy is key. Practice floating off the bottom in a shallow area first, and determine your exact weighting needs. With the correct buoyancy, you can avoid sinking and damaging reef habitat.
- Clip your alternate second stage regulator (octopus) to your Buoyancy Control Device (BCD) to prevent it from dragging across the reef.

Reef Ambassador Advice: Fishing

- Use circle hooks whenever possible, as fish have a hard time swallowing them. More released fish that survive, means more fish later!
- When bottom fishing, use braided line and a leader lighter than the breaking strength of the braid. In this way, you can leave minimal amounts of line on the reef if you are snagged.
- Only take what you need, rather than what you're allowed. More fish in the water leads to more successful reproduction, which in turns means more sustainable fishing for the future.

If you don't boat, fish or dive, you can still be a Coral Champion!

- Participate in any and all beach cleanups that you can attend.
- Recycle as much as possible, and deposit trash into receptacles for proper disposal. Millions of tons of trash ends up in the ocean that would otherwise be properly disposed of.
- Conserve water! Water purification takes a lot of energy, and it is always good to conserve energy.

Hawaii is first state to ban sale of certain sunscreens

Jefferson Graham, USA TODAY Published 11:40 a.m. ET July 4, 2018

(Photo: Reviewed.com)

Hawaii became the first state in the nation to begin enacting ban on the sale of sunscreens containing coral harming chemicals.

Hawaii Gov. David Ige signed the legislation on Tuesday, but it won't become effective until 2021.

The chemicals, oxybenzone and octinoxate, are believed by scientists to be toxic to coral reefs. The chemicals are in the majority of sunscreen products.

"This is just one small step toward protecting and restoring the resiliency of Hawaii's reefs," Ige said.

"Oxybenzone and octinoxate cause mortality in developing coral; increase coral bleaching that indicates extreme stress, even at temperatures below 87.8 degrees Fahrenheit; and cause genetic damage to coral and other marine organisms," according to the bill.

The governor added that Hawaii would also need to continue other efforts to protect coral, including fighting invasive species, pollution from land runoff and climate change.

State Rep. Chris Lee, who represents Honolulu suburbs, said the law is a necessary step to help Hawaii pass on its reefs, ocean, tourism industry and way of life to the next generation.

Leaders need to act quickly to save what coral world has left, he said.

"We know the tide is against us. We've got limited amount of time," Lee said.

Craig Downs, the executive director of Haereticus Environmental Laboratory told CNN that swimmers with sunscreen pollution would seriously damage the oceans. "You're going to see the slow decline of the coral reefs in the area. And then you get an undersea, desolate landscape of just muck and mud and sand."

Once the law goes into effect, sunscreen containing oxybenzone and octinoxate will only be available to those with a prescription from a physician. Others will have to buy sunscreens without these chemicals or bring their own sunscreen with them to Hawaii.

The group Retail Merchants of Hawaii has said it's concerned the ban will discourage people from buying sunscreen at brick and mortar stores.

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The New York Times

Palau Bans Many Kinds of Sunscreen, Citing Threat to Coral

By Vicky Xiuzhong Xu

Nov. 2, 2018

SYDNEY, Australia — The Western Pacific nation of Palau has become the first country to ban many kinds of sunscreen, in a move to protect its coral reefs from chemicals that scientists say cause significant damage.

Under the ban, which will take effect in 2020, "reef toxic" sunscreen — defined as containing one of 10 prohibited chemicals, a list that could grow later — can be confiscated from tourists when they enter the country, and retailers who sell it can be fined up to $1,000.

Damage to coral reefs worldwide from climate change has been widely reported, but scientists say there is growing evidence that chemicals from sunscreen, which washes off swimmers or enters the ocean through sewer systems, also causes grave harm.

Palau passed the ban into law last week. President Tommy Remengesau called it "especially timely," saying that a major impetus was a 2017 report that found sunscreen products to be "widespread" in Jellyfish Lake, one of the country's Unesco World Heritage sites.

What threat does sunscreen pose to coral?

It has been estimated that 14,000 tons of sunscreen are deposited in the world's oceans each year, and scientists say a number of studies have shown the product's adverse effects on coral reefs.

Researchers found that even a low concentration of sunscreen in the water can hinder the development of young coral, said Dr. Selina Ward, a lecturer in coral reef ecology and physiology at the University of Queensland in Australia. Studies have also shown that chemicals in sunscreen can cause localized coral bleaching, and can disrupt the reproduction of fish by interfering with their hormonal systems, Dr. Ward said.

Chemicals in sunscreen can be "bigger than climate change" in causing damage to reefs, Craig Downs, the executive director of the Haereticus Environmental Laboratory in Virginia, said this year. In 2015, Mr. Downs led a team that found that oxybenzone, which is commonly used in

sunscreen, stunts coral growth and is toxic for the algae that live within reefs, providing their color and performing other vital functions.

Have there been other sunscreen bans?

In May, Hawaii became the first state to ban the sale of sunscreen containing oxybenzone or octinoxate, another chemical that scientists say is damaging to coral. The ban is scheduled to go into effect in January 2021.

Nonbiodegradable sunscreen is banned in some parts of Mexico. At Xel-Há, a tourist development on the Riviera Maya, visitors can swap banned sunscreen for more coral-friendly varieties and get their own back when they leave.

What are the alternatives?

Not all sunscreens are "reef toxic." But "some of the sunscreens without these chemicals are quite expensive, which is a disincentive," Dr. Ward said. "I'm sure someone will get it soon, and put out these products at an affordable rate."

The most common commercial sunscreen brands contain oxybenzone, Dr. Ward said. But she also warned against mineral-based sunscreens containing zinc oxide. They were once considered safer for coral, she said, but a recent study found that zinc oxide can cause coral bleaching as well as microbial enrichment, causing more bacteria to form in the water.

"I think wearing fabrics on your body is the best alternative to sunscreen," she said. "We have stinger suits in the summer, when it's too hot for a wet suit. Cover your whole body in Lycra — an attractive look, if you can imagine."

She noted that reefs are under threat from major, global phenomena, including global warming and pollution of the oceans. By comparison, she said, sunscreen is "the one that we can solve."

What do others say?

Sunscreen manufacturers, not surprisingly, opposed the Hawaii ban. But they aren't alone in arguing that commercial sunscreens do more good than harm.

"At the moment, research on sunscreens' effects on coral is limited," said Heather Walker, chairwoman of the Cancer Council Australia's National Skin Cancer Committee. "By contrast, the evidence that sunscreen prevents skin cancer is conclusive. In this context, a ban is hasty."

Currently, Ms. Walker said, there is no accepted standard for what constitutes "environmentally friendly" sunscreen. "We would be concerned if Australians stopped using sunscreen more generally," she said.

Kim Do, a senior industry analyst at IBIS World, a market research company, said the new bans would cause sunscreen manufacturers to review the ingredients used in their products, though not immediately. She said the industry was "expected to continue undertaking product research and development to meet changing consumer demands."

A version of this article appears in print on Nov. 3, 2018, on Page A11 of the New York edition with the headline: To Protect Coral Reefs, Palau Bans Sunscreens

WORLD ECONOMIC FORUM

Protecting your skin could be harming the ocean - this is why

UVR filters from sunscreen have been linked to coral bleaching.
Image: REUTERS/David Gray

This article is published in collaboration with
The Conversation

08 Sep 2017

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An estimated 6,000-14,000 tons of sunscreen are deposited into coral reef areas of the sea every year. The chemicals we rub onto our skin might help prevent skin cancer but we're only just beginning to understand the environmental impact of sunscreen – and the initial assessments are not looking good. But early stage research suggests that nature might provide a solution to this

emerging problem if we can mimic the way that some plants and animals protect themselves from the sun.

Sunscreen is vital to helping prevent skin damage from ultraviolet radiation (UVR) that can cause melanoma and other skin cancers. They contain a number of ingredients that act as UVR filters, absorbing and scattering the radiation and stopping it from reaching the skin. Many studies have demonstrated the benefits of regular sunscreen use, including long-term studies in Australia that have shown reduced skin cancer rates..

The potential problem is that many ingredients used in sunscreen products are synthetic organic molecules, like those used to make plastics. These molecules are designed to be highly stable and so they don't break down when they enter the environment. As a result, sunscreen ingredients are detectable in species including fish, sea mammals such as dolphins and even marine dwelling birds.

The impact of these molecules on the environment isn't fully understood but is a growing focus of research. We know that some filters have a similar structure to the hormone oestrogen and mimic can its action. This can cause hormonal changes and even alter the sex characteristics of some fish. UVR filters have also been linked to coral bleaching.

These concerns are being monitored by many regulatory agencies. The European Chemicals Agency has listed eight out of the 16 most commonly used sunscreens in Europe as a potential threat to the environment and health, raising the ultimate possibility of a ban. Fears about damage to coral reef systems has already led to bans of particular sunscreen ingredients in some coral hotspots such as Hawaii.

These fears are currently relatively minor – but ways to improve the safety and biocompatibility of sunscreens need to be investigated. As is often the way, the answer may lie within the very environment that is being affected. Many marine species are continuously exposed to high levels of UVR throughout the day and have evolved efficient ways to prevent damage.

For example, microorganism species such as cyanobacteria and algae produce a group of compounds called mycosporine-like amino acids (MAA), which act as UVR filters. These are passed up the food chain to animals such as corals, invertebrates and fish, which then store the compounds in tissues exposed to UVR such as the skin, eyes and eggs. MAA efficiently absorb UVR and convert it to harmless light and heat, and aren't broken down by the radiation.

There is also evidence that these compounds can act as potent antioxidants, another very beneficial property that most synthetic filters don't have. Solar radiation can cause highly reactive atoms or molecules, known as free radicals, to break away from other bigger molecules. Free

radicals can cause what is known as oxidative damage to tissues, but they can be neutralised by antioxidants

The potential for these compounds to be applied to human health, particularly as sunscreens, is only just beginning to be explored. They have shown excellent potential in laboratory models. The next step is to translate this to human studies to truly understand their potential.

In the meantime, it's very important for public health that people don't stop using synthetic sunscreens. So far, there is only limited evidence for the potential ecological harm of sunscreens, especially at the concentrations at which UVR filters are found in the environment. But the effects of UVR on the skin are well known and proven beyond any doubt.

Written by

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This article is published in collaboration with The Conversation.

Explore context

Environment and Natural Resource Security

SCIENCE ENVIRONMENT

How Sunscreen May Be Destroying Coral Reefs

Justin Worland @justinworland Oct. 21, 2015

The effects of a chemical in sunscreen are toxic at the concentration equivalent to a drop of water in an Olympic pool

A chemical in sunscreen may be contributing to the destruction of the coral reefs as swimmers trying to protect their skin venture near reefs, according to new research.

Researchers behind the study, published in the journal *Archives of Environmental Contamination and* Toxicology, found that the chemical oxybenzone has toxic effects on young coral that causes endocrine disruption, DNA damage and death of coral, among other the problems. Oxybenzone also exacerbates coral bleaching, a process by which coral reject symbiotic organisms and lose their color. Bleaching has been particularly prevalent in recent years due to rising sea temperatures.

The Yomiuri Shimbun—AP

Corals are bleached on a seabed near Okinawa island on Aug. 26, 2013.

Currently, somewhere between 4,000 and 6,000 tons of sunscreen enters coral reef areas around the world each year, according to the U.S. National Park Service. That's a lot of sunscreen considering how little it takes to cause toxic effects. According to the new research, toxicity occurs at a concentration of 62 parts per trillion. That's the equivalent of a drop of water in an Olympic swimming pool, according to study author Omri Bronstein, a researcher at Tel Aviv University.

"Current concentrations of oxybenzone in these coral reef areas pose a significant ecological threat," Bronstein said in a press release.

Read More: Here's Why You May Soon Be Using Sunscreen in the Dark

Researchers were careful to note that they are not advocating the swimmers stop wearing sunscreen, which protects against skin cancer. Instead, they urged consumers to consider carefully what sunscreen they buy before swimming in the ocean. Sunscreens with titanium oxide or zinc oxide have not been found to harm reefs, according to the National Park Service. Additionally, swimmers can cover their upper body with long sleeve shirts or other apparel to reduce sunscreen use.

Sunscreen is part of a long list of threats to coral reefs that includes pollution, overfishing and climate change. Beyond their impressive appearance, coral reefs play an

important role for local communities and the world at large. For one, they contribute to local economies through tourism and sustain ecosystems where people can fish. One estimate from the National Oceanic and Atmospheric Administration put the economic contribution of coral reefs around the world at $30 billion each year. Reefs also protect the global environment by serving as carbon sinks, absorbing carbon dioxide that would otherwise contribute to global warming.

The Washington Post

Energy and Environment

How we are all contributing to the destruction of coral reefs: Sunscreen

By Darryl Fears October 20

The sunscreen that snorkelers, beachgoers and children romping in the waves lather on for protection is killing coral and reefs around the globe. And a new study finds that a single drop in a small area is all it takes for the chemicals in the lotion to mount an attack.

The study, released Tuesday, was conducted in the U.S. Virgin Islands and Hawaii several years after a chance encounter between a group of researchers on one of the Caribbean beaches, Trunk Bay, and a vendor waiting for the day's invasion of tourists. Just wait to see what they'd leave behind, he told the scientists – "a long oil slick." His comment sparked the idea for the research.

Not only did the study determine that a tiny amount of sunscreen is all it takes to begin damaging the delicate corals — the equivalent of a drop of water in a half-dozen Olympic-sized swimming pools — it documented three different ways that the ingredient oxybenzone breaks the coral down, robbing it of life-giving nutrients and turning it ghostly white.

[*Scientists say a dramatic worldwide coral bleaching event is underway*]

Yet beach crowds aren't the only people who add to the demise of the coral reefs found just off shore. Athletes who slather sunscreen on before a run, mothers who coat their children before outdoor play and people trying to catch some rays in the park all come home and wash it off.

Cities such as Ocean City, Md., and Fort Lauderdale, Fla., have built sewer outfalls that jettison tainted wastewater away from public beaches, sending personal care products with a cocktail of chemicals into the ocean. On top of that, sewer overflows during heavy rains spew millions of tons of waste mixed with stormwater into rivers and streams. Like sunscreen lotions, products like birth-control pills contain chemicals that are endocrine disruptors and alter the way organisms grow. Those are among the main suspects in an investigation into why male fish such

as bass are developing female organs.

Research for the new study was conducted only on the two islands. But across the world each year, up to 14,000 tons of sunscreen lotions are discharged into coral reef, and much of it "contains between 1 and 10 percent oxybenzone," the authors said. They estimate that places at least 10 percent of reefs at risk of high exposure, judging from how reefs are located in popular tourism areas.

[*Maryland's gigantic new oyster reef is a pearl that could save the Chesapeake Bay*]

"The most direct evidence we have is from beaches with a large amount of people in the water," said John Fauth, an associate professor of biology at the University of Central Florida in Orlando. "But another way is through the wastewater streams. People come inside and step into the shower. People forget it goes somewhere."

The study was published Tuesday in the journal Archives of Environmental Contamination and Toxicology. Fauth co-authored the study with Craig Downs of the nonprofit Haereticus Environmental Laboratory in Clifford, Va., and Esti Kramarsky-Winter, a researcher in the Department of Zoology at Tel Aviv University in Israel.

Their findings follow a National Oceanic and Atmospheric Administration study two weeks ago that said the world is in the midst of a third global coral bleaching event. It warned that pollution is undermining the health of coral, rendering it unable to resist bleaching or recover from the effects.

"The use of oxybenzone-containing products needs to be seriously deliberated in islands and areas where coral reef conservation is a critical issue," Downs said. "We have lost at least 80 percent of the coral reefs in the Caribbean. Any small effort to reduce oxybenzone pollution could mean that a coral reef survives a long, hot summer, or that a degraded area recovers."

[*As more bass switch sex, a strange fish story expands*]

Coral reefs are more than just exotic displays of color on the sea bed. The National Marine Fisheries Service, a division of the NOAA, placed their value for U.S. fisheries at $100 million. They spawn the fish humans eat and protect miles of coast from storm surge.

"Local economies also receive billions of dollars from visitors to reefs through diving tours, recreational fishing trips, hotels, restaurants, and other businesses based near reef ecosystems," NOAA said on its Web site. "Globally, coral reefs provide a net benefit of $9.6 billion each year from tourism and recreation revenues, and $5.7 billion per year from fisheries."

Oxybenzone is mixed in more than 3,500 sunscreen products worldwide, including popular brands such as

Coppertone, Baby Blanket Faces, L'Oreal Paris, Hawaiian Tropic and Banana Boat. Adverse effects on coral started on with concentrations as low as 62 parts per trillion. There are alternative sunscreens with no oxybenzone, including a product called Badger Natural Sunscreen and dozens of others on a list provided by the non-profit Environmental Working Group.

Measurements of oxybenzone in seawater within coral reefs in Hawaii and the U.S. Virgin Islands found concentrations ranging from 800 parts per trillion to 1.4 parts per million," according to the authors. That's 12 times the concentrations needed to harm coral.

"This study raises our awareness of a seldom-realized threat to the health of our reef life ... chemicals in the sunscreen products visitors and residents wear are toxic to young corals," said Pat Lindquist, executive director of the Napili Bay and Beach Foundation in Maui. "This knowledge is critical to us as we consider actions to mitigate threats or improve on current practices."

Read more in Science and Energy & Environment:

The big fish story everyone is missing in the western drought

Sea stars are wasting away in larger numbers on a wider scale in two oceans

Crabs are bulking up on carbon pollution to become giants

For more, you can sign up for our weekly newsletter here, and follow us on Twitter here.

Darryl Fears has worked at The Washington Post for more than a decade, mostly as a reporter on the National staff. He currently covers the environment, focusing on the Chesapeake Bay and issues affecting wildlife.

National Park Service

National Park Service
U.S. Department of the Interior

South Florida, Hawaii, U.S. Virgin Islands, American Samoa

Protect Yourself, Protect The Reef!

NPS Photos by Thomas M. Strom

The impacts of sunscreens on our coral reefs

Discovering an underwater wonderland

A day on the water can be exciting and create lasting memories. When it comes to experiencing the coral reef, snorkeling and diving are the best ways to get up-close and personal. When we enter the water to explore these fascinating places, we may not consider the products that are rinsing off our bodies and how they may affect the tiny animals that make up our fragile coral reefs.

Our living reefs

Coral reefs are among the most biologically diverse ecosystems in the world, and have even been called "biodiversity hotspots." They cover less than 1% of the ocean's floor, but nearly one million species of fish, invertebrates, and algae are estimated to live in and around the world's reefs.

Corals are made up of tiny soft-bodied animals called polyps. They belong to a group called "Cnidaria" which includes species such as sea anemones and jellyfish. Symbiotic algae, called zooxanthellae, live within the coral polyps making them "solar powered" and provide coral with food energy through the process of photosynthesis. These algae give coral its vibrant colors, such as green, brown, or orange. The polyps of "stony" corals use calcium from seawater to manufacture cup-like limestone skeletons. Generations of polyps create adjoining cups that result in fantastically-shaped colonies resembling flowers, mountains, or animal antlers. When many colonies of various species grow in close proximity to each other, they create the living fortresses we call reefs.

Concerns and the steps we can take

Our understanding of coral reefs is constantly growing, and now we know that more than 60% of coral reefs are at risk of being impacted by a variety of sources including marine pollutants, overfishing, boat groundings, and disease. Each of us can take steps to reduce these effects. One step is to limit what we bring into the water.

Sunscreens: the double-edged sword

Sunscreens are among the products we are encouraged to use liberally to protect ourselves from the sun's harmful rays. However, researchers are finding that while protecting humans, some compounds in many sunscreens can harm the coral on our reefs. Researchers testing the effects of sunscreen on corals explain that chemicals in sunscreen can awaken coral viruses. The coral then becomes sick and expel their life-giving algae. Without these algae, the coral "bleaches" (turns white), and often dies.

We may not realize that the products covering our skin wash off when we enter the water, and it adds up! Research tells us that 4,000 to 6,000 TONS of sunscreen enters reef areas annually. This does not spread out rapidly or evenly over the entire ocean, but concentrates on popular tourist sites. It is estimated that 90% of snorkeling/diving tourists are concentrated on 10% of the world's reefs. This means that our most popular reefs, such as those in our national parks, are exposed to the majority of sunscreens.

Be reef friendly

As a visitor to the park and the reefs, you can reduce the risk of harming coral by taking a more "reef friendly" approach to sun protection.

CHECK THE LABELS: While no sunscreen has been proven to be completely 'reef-friendly,' those with titanium oxide or zinc oxide, which are natural mineral ingredients, have not been found harmful to corals. Sunscreens sold for children or for those with sensitive skin may contain these gentler compounds as the active ingredients.

COVER UP: You can protect yourself as well as the reef by 'covering-up' before you enter the water. On the water, wear hats, sunglasses and light, long-sleeved clothing to protect you. In the water, a long-sleeved shirt or rash guard will help prevent sunburn.

Remember, if it's on your skin, it's on the reef. Be reef friendly! Reduce the amount of sunscreen you leave behind...

THE LANCET
Planetary Health

COMMENT | VOLUME 2, ISSUE 11, PE465-E466, NOVEMBER 01, 2018

Sunscreens, cancer, and protecting our planet

Jayden Galamgam • Natalia Linou • Eleni Linos

Open Access • Published: November, 2018 • DOI: https://doi.org/10.1016/S2542-5196(18)30224-9 •

Beginning Jan 1, 2021, Hawaii will ban the sale or distribution of any sunscreens containing oxybenzone or octinoxate without a prescription from a licensed health-care provider. The ban is the result of concerns about the detrimental effects of these chemicals on coral and other marine organisms. Coral reefs are among the most important parts of marine ecosystems, providing food and shelter for ocean species, and offering vital services to human societies through their role in coastal protection, building materials, fisheries, and tourism. However, coral reef ecosystems have been threatened by climate change, ocean acidification, and coastal pollution.[1, 2] Meanwhile, the incidence of malignant melanoma and non-melanoma skin cancers continue to rise,[3] and public health efforts have focused on increasing sun protection practices. It is time to think about skin cancer and its prevention in the context of planetary health,[4] to balance the benefits to human health with the preservation of our environment and the ecosystems that underpin it.

Excessive ultraviolet radiation exposure is a preventable cause of all types of skin cancer,[5] with numerous studies confirming that exposure in childhood and adolescence increases the risk of skin cancer later in life, especially when resulting in severe sunburn.[6, 7] Although long-term randomised trials of sunscreen on ncer prevention are still needed, it is widely established that broad-spectrum chemic ph :ens reduce sunburn, one of the main risk factors for skin cancer.

Several methods for effectively protecting skin from excessive ultraviolet radiation exposure and sunburn exist, including the use of protective clothing and hats, avoiding midday sun, and seeking shade. Broad-spectrum sunscreen of sun protection factor 30 or greater is an important supplement to these behaviours, especially for areas of the body that are not covered by clothing. Some dermatologists and public health professionals might therefore question whether Hawaii's decision to ban certain chemical sunscreens was the right one. We believe that based on the precautionary principle that encourages policies that protect human health and the environment in the face of uncertain risks and the fact that there are many safe alternatives that people can use until this uncertainty is resolved, this is not the wrong decision.

We reviewed the scientific data on the effects of sunscreens on the environment. Overall, we identified very few studies on the topic, suggesting it might be too soon to draw firm conclusions. However, in laboratory conditions, oxybenzone was toxic to corals and led to coral bleaching,[8, 9] a process by which corals that are stressed by changes in environmental conditions expel the symbiotic algae living in their tissues, causing them to turn white. Up to an estimated 14 000 tonnes of sunscreens, of which many contain as much as 10% oxybenzone, are washed off in tourist reef areas annually.[9] Ultraviolet filters might also enter the ocean through wastewater treatment plant effluent. In Brazil, oxybenzone and octinoxate were identified in both raw and treated water.[10] The effects of oxybenzone on other marine life have also been studied. In Japanese medaka and rainbow trout, exposure to high concentrations of oxybenzone led to decreased egg production, with significant reductions in egg hatchings and possible feminisation of male fish.[11] These documented effects on coral and marine life call the aforementioned precautionary principle into play.[12]

Planetary health is an emerging field focused on the dual goal of protecting the health of humans while also protecting the health of our planet for today's and future generations. This approach was developed because of the threatened state of the environment and a realisation that human behaviours have led to a transgression of several planetary boundaries, putting the health of both humans and the planet at risk. Dermatologists should be familiar with this problem, given that stratospheric ozone depletion, as evident in the hole in the ozone layer, has put many humans at increased risk of malignant melanoma and other cancers.

We clearly need further studies to better evaluate the potential environmental effects of sunscreen. In the meantime, both dermatologists and sunscreen sceptics agree on the benefits of other sun-protective behaviours, including avoiding indoor tanning, seeking shade, and wearing sun-protective clothing and sunscreens with physical filters including zinc oxide and titanium dioxide.[13] It is time for dermatologists to

ıe advocating for skin cancer prevention, while also being cognisant of the understuc ıt

potential risks to our planet. And for Hawaiians, He po'i na kai uli, kai ko'o, 'a'ohe hina pūko'a. Though the sea be deep and rough, the coral rock remains standing. Hopefully, for generations to come.

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CORRESPONDENCE | VOLUME 376, ISSUE 9736, P161-162, JULY 17, 2010

The questionable effectiveness of sunscreen

Adam E Handel • Sreeram V Ramagopalan

Published: July 17, 2010 • DOI: https://doi.org/10.1016/S0140-6736(10)61104-X

In their Seminar (Feb 20, p 673),[1] Vishal Madan and colleagues highlight a rising incidence of non-melanoma skin cancer (NMSC) in several countries. The incidence of NMSC also seems to be increasing in the USA.[2] This increase is the reverse of what is expected given the continued increased purchase of sunscreen per head in the USA and UK since the 1990s (figure).[3, 4]

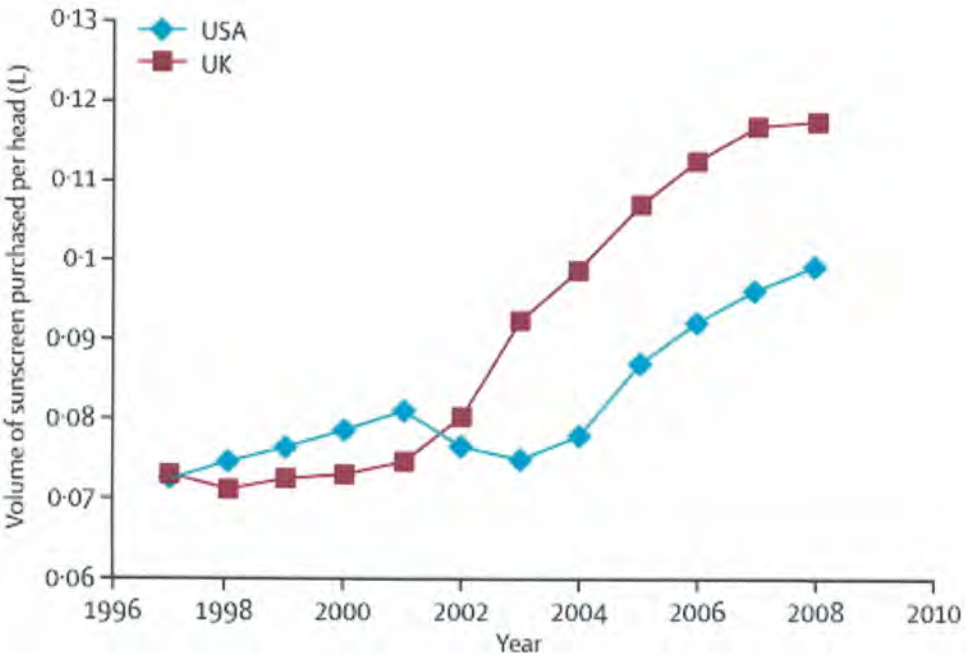

Figure Purchase of sunscreen products by volume per head over time in the USA and UK[3, 4]

View Large Image | Download Hi-res image | Download (PPT)

Hydrobiologia
DOI 10.1007/s10750-016-2746-2

PRIMARY RESEARCH PAPER

Direct and indirect effects of sunscreen exposure for reef biota

Shaun M. McCoshum · Alicia M. Schlarb · Kristen A. Baum

Received: 4 January 2016 / Revised: 11 March 2016 / Accepted: 15 March 2016

Abstract Coral reefs are ecologically and economically important, contributing to both fishing and ecotourism economies around the world. Tourism and recreational activities have increased in coastal areas and so has the use of sunscreen. Sunscreen reduces human exposure to harmful UV rays, but washes off during aquatic recreational activities, which may negatively affect reef biota. To evaluate how sunscreen affects coral reef ecosystems, we added sunscreen at concentrations similar to previous studies to growing environments containing flatworms (*Convolutriloba macropyga*) with symbiotic algae, photosynthetic diatoms (*Nitzschia sp.*), *Aiptasia* anemones, and pulse corals (*Xenia sp.*). Using behavioral observations and estimates of population and colony growth, we show nominal concentrations of sunscreen negatively affect all of the studied species. Furthermore, we show that mobile flatworms do not avoid water which contains sunscreen and flatworms exposed to sunscreen prefer darker conditions. Based on our results, beach goers should limit use of sunscreens when near coral reefs and consider alternative protective measures, such as the utilization of sun-protective clothing.

Keywords Sunscreen · Ecotourism · Coral reef · Soft coral · Contamination · Flatworms · Anemone

Introduction

Coral reef ecosystems are integral parts of the global economy, including fisheries and tourism (Sundseth, 2000; UNWTO, 2014), and face numerous threats worldwide from ocean acidification and rising sea temperatures (Bellwood et al., 2004; Reyes-Nivia et al., 2013) to eutrophication and sedimentation (Bellwood et al., 2004; Bartley et al., 2014). In many areas, coral reefs are threatened and degraded by overharvesting and human exploitation (McClanahan & Muthiga, 1988), including coastal recreation and tourism which are among the fastest growing industries in the world. The impacts stemming from mass tourism have been investigated (Davenport & Davenport, 2006; Kowalewski et al., 2014), but few studies have evaluated the ecological impact of commercial sunscreen use by tourists (Tovar-Sánchez et al., 2013). Due to tourism, approximately 10% of the world's reefs are threatened by sunscreen pollution (Danovaro et al., 2008). Therefore, it is important to understand how sunscreen is affecting reef biota in order to

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Baseline

An environmental risk assessment of three organic UV-filters at Lac Bay, Bonaire, Southern Caribbean

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ABSTRACT

Although organic UV filters (OUVFs) benefit human health by preventing skin burns and cancer, several studies revealed that organic UV filters can induce developmental and reproductive toxicity to aquatic organisms. Discharge of OUVFs occurs predominantly at marine recreational hotspots, such as Lac Bay, Bonaire, and is predicted to increase significantly due to growing tourism worldwide. Unfortunately, there is no insight what the current and future discharge of OUVF at Lac Bay is. Therefore, this study aimed to 1) measure concentrations and estimate the risk of specific OUVFs to different nursery habitats at Lac Bay, and 2) compare measured and predicted concentration based risk assessment outcome. Results showed that at least one of the three nurseries at Lac Bay had a potential for adverse effects. Furthermore, predicted environmental concentrations of UV filter discharge can be applied to gain more insight in the order of extent of OUVF discharge by marine tourism.

UV Filters are cosmetic ingredients that absorb or reflect the UV rays that are part of sunlight. UV filters are among others used to protect the skin from the harmful effects of UV light and is most commonly used in sunscreen products. Despite the many advantages of sunscreen in preventing skin aging and skin cancer, the release of sunscreen in the environment and its effect on environmental health raises concerns. Several studies described reproductive and developmental toxicity to fish and corals by exposure of specific organic UV filters, such as oxybenzone and octocrylene (Downs et al., 2014; Downs et al., 2016; Danovaro et al., 2008; Zhang et al., 2016; Kim et al., 2014; Balázs et al., 2016; Blüthgen et al., 2014; Paredes et al., 2014). In addition, organic UV filters were found to accumulate in aquatic biota, including in sea urchins, clams, fish and dolphins (Gago-Ferrero et al., 2015; Alonso et al., 2015; Ramos et al., 2015; Blüthgen et al., 2012; Blüthgen et al., 2014). Since concentrations in (coastal) biota were found to be positively correlated with UV radiation, recreational pressure and temperature (Bachelot et al., 2012; Groz et al., 2014; Amine et al., 2012; Bratkovics et al., 2015), sunscreen discharge and accumulation is therefore likely to occur at popular tropical marine recreation hotspots, such as the Caribbean island Bonaire.

Lac Bay is a popular touristic 700 ha lagoon at Bonaire and is more than a marine recreational hotspot. The lagoon comprises important nursery habitats, such as a back reef, mangroves, and seagrass beds, which support reef fish abundance in the reefs around the island (Nagelkerken et al., 2000, 2002; Nagelkerken and van der Velde, 2004). In addition, Lac Bay inhabits many endangered and threatened coral species such as *Acropora palmata*, *A. cervicornis* and *A. prolifera*, and other IUCN listed organisms (Debrot et al., 2010). Healthy ecosystems are of great importance for the Bonairean society in terms of economic as well as human wellbeing (Van der Lely et al., 2013). The tourism industry at Bonaire is a large driver to the economy, whereby, relative to the 20,000 residents, approximately 130,000 tourists visited the island by airplane and 235,000 by cruise ship each year (CBS, 2017). For the Bonairean society, it is of great importance to maintain the environmental health of Lac Bay's ecosystem.

Since recreational pressure at coastal ecosystems will increase by expected increasing tourism (UNWTO, 2011), sunscreen discharge is expected to increase as well. Uncontrolled development of marine recreation hotspots, such as Lac Bay, will probably result to marine water contamination whereby the carrying capacity of this area could be affected (Debrot, 2012). Unfortunately, there is no insight what the current and future discharge or contamination of UV filters at Lac Bay is. It is therefore of great importance to define the current status, and thereby the risk of UV filter exposure towards Lac Bay's ecosystem. Due to cost- and time-effective, logistic, and management reasons, it is worthwhile to investigate if emissions and field concentrations can be predicted by tourism data and if these predicted concentrations could be a good substitute for monitoring and preliminary risk analysis

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Sunscreen bans: Coral reefs and skin cancer.

Raffa RB[1,2,3], Pergolizzi JV Jr[3,4], Taylor R Jr[4], Kitzen JM[5]; NEMA Research Group.

Author information

Abstract

WHAT IS KNOWN AND OBJECTIVE: Hawaii will ban two major ingredients of sunscreens. This article reviews the reasons and future directions. Hawaii recently enacted legislation that will ban the use of two major ingredients of the majority of commonly used sunscreens. The reason for the ban is the ingredients' putative deleterious impact on marine ecosystems, particularly **coral reefs**. But sunscreens also save lives by decreasing the risk of UV-induced skin cancers. We review both sides of the issue and potential implications for the healthcare system.

COMMENT: Coral reefs consist of organisms in delicate equilibria that are susceptible to small changes in their surroundings. Recent natural and man-made disruptions, direct or indirect, such as changes in ocean temperature and chemistry, ingress of invasive species, pathogens, pollution and deleterious fishing practices, have been blamed for the poor health, or even the outright destruction, of some **coral reefs**. The most popular **sunscreen** products contain two ingredients-oxybenzone and octinoxate-that have also been implicated in **coral** toxicity and will be banned. This creates a healthcare dilemma: Will the protection of **coral reefs** result in an increase in human skin cancers?

WHAT IS NEW AND CONCLUSION: Concentration estimates and mechanism studies support an association-direct or indirect (via promotion of viral infection)-of sunscreens with bleaching of **coral reefs**. A ban on the two most common **sunscreen** ingredients goes into effect in Hawaii on January 1, 2021. Proponents suggest that this is a trend, just the first of many such bans worldwide; opponents warn of a dire increase in human skin cancers. As a result, alternative **sunscreen** compounds are being sought.

KEYWORDS: coral reef; octinoxate; oxybenzone; skin cancer; **sunscreen**

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Skinmed. 2018 Jul 1;16(4):223-229. eCollection 2018.

Can Sunscreens Harm Coral Reefs? Addressing Environmental Concerns and Offering Practical Recommendations.

Zirwas MJ[1], Andrasik W[2].

Author information

Abstract

The crucial role **sunscreen** plays in preventing sunburns, photoaging, and skin cancer is unquestionable, and as a result, it is incumbent upon dermatologists to influence patients to appropriately use sunscreens. In addition to explaining the benefits of **sunscreen** use and how to properly use **sunscreen**, dermatologists must also address possible barriers or concerns that patients may have regarding **sunscreen**. One concern that has gained increasing media attention in the recent years has been the environmental impact of sunscreens, especially the impact on **coral reefs**. There is strong evidence that some **sunscreen** ingredients, especially oxybenzone, are harmful to corals if the concentration in water is high. In some situations, primarily related to the number of swimmers and the geography of the shoreline, concentrations of oxybenzone far exceed the levels shown to be harmful to corals. As advocates for our patients' skin health, we need to be prepared to address this issue when asked, so that patients do not forgo **sunscreen** use in an effort to protect corals. This article will review evidence regarding the effects of **sunscreen** ingredients on corals and will provide practical guidance for counseling patients on how to select sunscreens that minimize the potential for harm to **coral reefs**.

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J Am Acad Dermatol. 2019 Jan;80(1):266-271. doi: 10.1016/j.jaad.2018.06.033. Epub 2018 Nov 14.

Review of environmental effects of oxybenzone and other sunscreen active ingredients.

Schneider SL[1], Lim HW[2].

Author information

Abstract

With increasing awareness regarding the risks of sunburn, photoaging, and skin cancer, the use of sunscreens has increased. Organic and inorganic filters are used in **sunscreen** products worldwide. Concerns have been raised regarding the environmental effects of commonly used organic ultraviolet (UV) filters, including oxybenzone (benzophenone-3), 4-methylbenzylidene camphor, octocrylene, and octinoxate (ethylhexyl methoxycinnamate). Studies have identified UV filters such as oxybenzone, octocrylene, octinoxate, and ethylhexyl salicylate in almost all water sources around the world and have commented that these filters are not easily removed by common wastewater treatment plant techniques. Additionally, in laboratory settings, oxybenzone has been implicated specifically as a possible contributor to **coral reef** bleaching. Furthermore, UV filters such as 4-methylbenzylidene camphor, oxybenzone, octocrylene, and octinoxate have been identified in various species of fish worldwide, which has possible consequences for the food chain. As dermatologists, it is important for us to continue to emphasize the public health impact of excessive sun exposure and advise our patients about proper photoprotection practice, which consists of seeking shade, wearing photoprotective clothing (including hats and sunglasses), and applying appropriate sunscreens.

KEYWORDS: 3,4-methylbenzylidenecamphor; benzophenone; butyl methoxydibenzoylmethane; ethylhexyl methoxycinnamate; ethylhexyl salicylate; nonmelanoma skin cancer; octocrylene; octyl methoxycinnamate; oxybenzone; **sunscreen**; ultraviolet radiation

PMID: 29981751 DOI: 10.1016/j.jaad.2018.06.033

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Impact of inorganic UV filters contained in sunscreen products on tropical stony corals (Acropora spp.).

Corinaldesi C[1], Marcellini F[2], Nepote E[3], Damiani E[3], Danovaro R[4].

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Abstract

Most **coral reefs** worldwide are threatened by natural and anthropogenic impacts. Among them, the release in seawater of **sunscreen** products commonly used by tourists to protect their skin against the harmful effects of UV radiations, can affect tropical corals causing extensive and rapid bleaching. The use of inorganic (mineral) filters, such as zinc and titanium dioxide (ZnO and TiO_2) is increasing due to their broad UV protection spectrum and their limited penetration into the skin. In the present study, we evaluated through laboratory experiments, the impact on the corals Acropora spp. of uncoated ZnO nanoparticles and two modified forms of TiO_2 (Eusolex®T2000 and Optisol™), largely utilized in commercial sunscreens together with organic filters. Our results demonstrate that uncoated ZnO induces a severe and fast **coral** bleaching due to the alteration of the symbiosis between **coral** and zooxanthellae. ZnO also directly affects symbiotic dinoflagellates and stimulates microbial enrichment in the seawater surrounding the corals. Conversely, Eusolex® T2000 and Optisol™ caused minimal alterations in the symbiotic interactions and did not cause bleaching, resulting more eco-compatible than ZnO. Due to the vulnerability of **coral reefs** to anthropogenic impacts and global change, our findings underline the need to accurately evaluate the effect of commercial filters on stony corals to minimize or avoid this additional source of impact to the life and resilience ability of **coral reefs**.

KEYWORDS: **Coral** bleaching; Inorganic filters; Sunscreens; Titanium dioxide; Zinc oxide

PMID: 29801220 DOI: 10.1016/j.scitotenv.2018.05.108

[Indexed for MEDLINE]

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Ecotoxicology. 2014 Mar;23(2):175-91. doi: 10.1007/s10646-013-1161-y. Epub 2013 Dec 19.

Toxicological effects of the sunscreen UV filter, benzophenone-2, on planulae and in vitro cells of the coral, Stylophora pistillata.

Downs CA[1], Kramarsky-Winter E, Fauth JE, Segal R, Bronstein O, Jeger R, Lichtenfeld Y, Woodley CM, Pennington P, Kushmaro A, Loya Y.

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Abstract

Benzophenone-2 (BP-2) is an additive to personal-care products and commercial solutions that protects against the damaging effects of ultraviolet light. BP-2 is an "emerging contaminant of concern" that is often released as a pollutant through municipal and boat/ship wastewater discharges and landfill leachates, as well as through residential septic fields and unmanaged cesspits. Although BP-2 may be a contaminant on **coral reefs**, its environmental toxicity to **reefs** is unknown. This poses a potential management issue, since BP-2 is a known endocrine disruptor as well as a weak genotoxicant. We examined the effects of BP-2 on the larval form (planula) of the **coral**, Stylophora pistillata, as well as its toxicity to in vitro **coral** cells. BP-2 is a photo-toxicant; adverse effects are exacerbated in the light versus in darkness. Whether in darkness or light, BP-2 induced **coral** planulae to transform from a motile planktonic state to a deformed, sessile condition. Planulae exhibited an increasing rate of **coral** bleaching in response to increasing concentrations of BP-2. BP-2 is a genotoxicant to corals, exhibiting a strong positive relationship between DNA-AP lesions and increasing BP-2 concentrations. BP-2 exposure in the light induced extensive necrosis in both the epidermis and gastro dermis. In contrast, BP-2 exposure in darkness induced autophagy and autophagic cell death.The LC50 of BP-2 in the light for an 8 and 24 hour exposure was 120 parts per million (ppm) and 165 parts per billion (ppb), respectively. The LC50s for BP-2 in darkness for the same time points were 144 parts per million and 548 parts per billion [corrected].

PMID: 24352829 DOI: 10.1007/s10646-013-1161-y

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MeSH terms, Substances

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Environ Health Perspect. 2008 Apr;116(4):441-7. doi: 10.1289/ehp.10966.

Sunscreens cause coral bleaching by promoting viral infections.

Danovaro R[1], Bongiorni L, Corinaldesi C, Giovannelli D, Damiani E, Astolfi P, Greci L, Pusceddu A.

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Abstract

BACKGROUND: Coral bleaching (i.e., the release of **coral** symbiotic zooxanthellae) has negative impacts on biodiversity and functioning of **reef** ecosystems and their production of goods and services. This increasing world-wide phenomenon is associated with temperature anomalies, high irradiance, pollution, and bacterial diseases. Recently, it has been demonstrated that personal care products, including sunscreens, have an impact on aquatic organisms similar to that of other contaminants.

OBJECTIVES: Our goal was to evaluate the potential impact of **sunscreen** ingredients on hard corals and their symbiotic algae.

METHODS: In situ and laboratory experiments were conducted in several tropical regions (the Atlantic, Indian, and Pacific Oceans, and the Red Sea) by supplementing **coral** branches with aliquots of sunscreens and common ultraviolet filters contained in **sunscreen** formula. Zooxanthellae were checked for viral infection by epifluorescence and transmission electron microscopy analyses.

RESULTS: Sunscreens cause the rapid and complete bleaching of hard corals, even at extremely low concentrations. The effect of sunscreens is due to organic ultraviolet filters, which are able to induce the lytic viral cycle in symbiotic zooxanthellae with latent infections.

CONCLUSIONS: We conclude that sunscreens, by promoting viral infection, potentially play an important role in **coral** bleaching in areas prone to high levels of recreational use by humans.

KEYWORDS: UV filters; bleaching; corals; sunscreens; viruses

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Sunscreen Products as Emerging Pollutants to Coastal Waters

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Abstract

A growing awareness of the risks associated with skin exposure to ultraviolet (UV) radiation over the past decades has led to increased use of sunscreen cosmetic products leading the introduction of new chemical compounds in the marine environment. Although coastal tourism and recreation are the largest and most rapidly growing activities in the world, the evaluation of sunscreen as source of chemicals to the coastal marine system has not been addressed. Concentrations of chemical UV filters included in the formulation of sunscreens, such as benzophehone 3 (BZ-3), 4-methylbenzylidene camphor (4-MBC), TiO_2 and ZnO, are detected in nearshore waters with variable concentrations along the day and mainly concentrated in the surface microlayer (i.e. 53.6–577.5 ng L^{-1} BZ-3; 51.4–113.4 ng L^{-1} 4-MBC; 6.9–37.6 μg L^{-1} Ti; 1.0–3.3 μg L^{-1} Zn). The presence of these compounds in seawater suggests relevant effects on phytoplankton. Indeed, we provide evidences of the negative effect of sunblocks on the growth of the commonly found marine diatom *Chaetoceros gracilis* (mean $EC_{50} = 125 \pm 71$ mg L^{-1}). Dissolution of sunscreens in seawater also releases inorganic nutrients (N, P and Si forms) that can fuel algal growth. In particular, PO_4^{3-} is released by these products in notable amounts (up to 17 μmol PO_4^{3-} g^{-1}). We conservatively estimate an increase of up to 100% background PO_4^{3-} concentrations (0.12 μmol L^{-1} over a background level of 0.06 μmol L^{-1}) in nearshore waters during low water renewal conditions in a populated beach in Majorca island. Our results show that sunscreen products are a significant source of organic and inorganic chemicals that reach the sea with potential ecological consequences on the coastal marine ecosystem.

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Introduction

In spite of the fact that coastal tourism and recreation are becoming the largest and most rapidly growing activities in the world [1] and that sunscreen products have been used for nearly 80 years, the effect of sunscreens, as a source of introduced chemicals to the coastal marine system, has not yet been addressed. Sun protection cosmetics are composed of organic (para-aminobenzoates, cinnamates, benzophenones, dibenzoylmethanes, camphor derivatives and benzimidazoles, which absorb the UV radiations), and/or inorganic UV chemical filters (i.e. TiO_2 and ZnO) that reflect and scatter the UV radiation protecting human skin from direct radiation of sunlight [2,3]. There are around 45 UV chemical filters subjected to regulation in different countries [3,4]. In addition to these UV filters, sunscreen products contain other ingredients such as preservatives (e.g. parabens derivates) [5], coloring agents (e.g. ammonium sulphate, copper powder, ferric ammonium ferrocyanide, iron and zinc oxides, etc.) [6], film forming agents (e.g. acrylates and acrylamides) [7], surfactants, chelators, viscosity controllers (e.g. potassium cetyl phosphate, pentasodium ethylenediamine tetramethylene phosphonate among others) [8] and fragrances, etc. Formulation and concentration of cosmetic ingredients in commercial sunscreens are varied, and legislated by local or international agencies (e.g. European Union Cosmetics Directive [9] or United States Food and Drug Administration [10]) to reach a compromise between adequate UV protection and minimal side effects for humans [2]. Studies conducted in lakes (i.e. Zurich and Hüttnersee Lakes, Swiss) suggest that UV filter removal processes from the water column are important, and can be mediated by biodegradation processes and/or absorption sedimentation [11]. Because of their lipophilicity, persistence and stability against biodegradation they have been shown to accumulate in the food chain [4,12].

Coastal tourism is considered one of the fastest growing forms of tourism in recent decades [1] being the Mediterranean one of the most important tourism regions in the world [13]. For decades, the Balearic Islands (Western Mediterranean Sea) have provided the traditional sun, sand and sea product. Tourism is the first economic activity in the Islands. The islands comprise a total surface area of 5040 km^2, 1428 km of coastline and have usually been considered in the literature as a typical example of a second-generation european mass tourist resort [14]. Majorca island (the

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An environmental risk assessment of three organic UV-filters at Lac Bay, Bonaire, Southern Caribbean.

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Abstract

Although organic UV filters (OUVFs) benefit human health by preventing skin burns and cancer, several studies revealed that organic UV filters can induce developmental and reproductive toxicity to aquatic organisms. Discharge of OUVFs occurs predominantly at marine recreational hotspots, such as Lac Bay, Bonaire, and is predicted to increase significantly due to growing tourism worldwide. Unfortunately, there is no insight what the current and future discharge of OUVF at Lac Bay is. Therefore, this study aimed to 1) measure concentrations and estimate the risk of specific OUVFs to different nursery habitats at Lac Bay, and 2) compare measured and predicted concentration based risk assessment outcome. Results showed that at least one of the three nurseries at Lac Bay had a potential for adverse effects. Furthermore, predicted environmental concentrations of UV filter discharge can be applied to gain more insight in the order of extent of OUVF discharge by marine tourism.

KEYWORDS: Octocrylene; Oxybenzone; **Sunscreen** products; Tourism; UV filters

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Comparative toxicities of four benzophenone ultraviolet filters to two life stages of two coral species.

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Abstract

The benzophenone (BP) organic ultraviolet (UV) filters have been measured in seawater at ng/L to μg/L levels, but more data on their effects in non-target marine organisms are needed. Corals can be exposed to BPs due to wastewater discharges and coastal recreational activities. In this study, toxicities and bioaccumulation of BP-1 (2,4-dihydroxybenzophenone), BP-3 (oxybenzone), BP-4 (sulisobenzone) and BP-8 (dioxybenzone) to larvae and adults of two **coral** species, Pocillopora damicornis and Seriatopora caliendrum, were assessed at concentrations ranging from 0.1-1000 μg/L. BP-1 and BP-8 exposure caused significant settlement failure, bleaching and mortality of S. caliendrum larvae [lowest observed effect concentration (LOEC): ≥10 μg/L] compared to the other BPs, while none of the tested compounds and concentrations affected P. damicornis larvae. Nubbins were more sensitive to BP-3, BP-1 and BP-8 than larvae. Overall, BP-1 and BP-8 were more toxic to the two tested species than BP-3 and BP-4, which matches the relative bioaccumulation potential of the four BPs (BP-8 > BP-1 ≈ BP-3 > BP-4). A conservative risk assessment using the effect concentrations derived from this study showed that BP-3, BP-1 and BP-8 pose high or medium risk to the health of corals in popular recreational areas of Taiwan and Hong Kong. Our study suggests that future ecotoxicological studies of corals should take their sensitivities, life stages and metabolic capacities into consideration.

KEYWORDS: Benzophenone ultraviolet filter; Bioaccumulation; Biodegradation; Risk assessment; Scleractinia

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Exposure patterns of UV filters, fragrances, parabens, phthalates, organochlor pesticides, PBDEs, and PCBs in human milk: Correlation of UV filters with use of cosmetics

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ABSTRACT

In order to assess potential risks of exposure to environmental chemicals, more information on concomitant exposure to different chemicals is needed. We present data on chemicals in human milk of a cohort study (2004, 2005, 2006) of 54 mother/child pairs, where for the first time, cosmetic UV filters, synthetic musks, parabens and phthalate metabolites were analyzed in the same sample along with persistent organochlor pollutants (POPs), i.e., organochlor pesticides and metabolites, polybrominated diphenylethers and polychlorinated biphenyls (PCBs). The two groups of chemicals exhibited different exposure patterns. Six out of seven PCB congeners and a majority of pesticides were present in all milk samples, with significant correlations between certain PCB congener and pesticide levels, whereas the cosmetic-derived compounds, UV filters, parabens and synthetic musks, exhibited a more variable exposure pattern with inter-individual differences. UV filters were present in 85.2% of milk samples, in the range of PCB levels. Comparison with a questionnaire revealed a significant correlation between use of products containing UV filters and their presence in milk for two frequently used and detected UV filters, 4-methylbenzylidene camphor and octocrylene, and for the whole group of UV filters. Concentrations of PCBs and organochlor pesticides were within ranges seen in Western and Southern European countries. For several POPs, mean and/or maximum daily intake calculated from individual concentrations was above recent US EPA reference dose values. Our data emphasize the need for analyses of complex mixtures to obtain more information on inter-individual and temporal variability of human exposure to different types of chemicals.

1. Introduction

Humans are exposed to a mixture of many different contaminants. However, there are few comparative studies on the simultaneous presence of different types of chemicals in the same human sample that would allow for cross-comparisons of exposure. This is particularly important in the case of endocrine disrupting chemicals (EDCs), which belong to a large range of different chemicals. EDCs present in our environment, in food and consumer products cause growing concern because of their potential to interfere with homoeostatic control and reproduction (Andersson et al., 2008; Diamanti-Kandarakis et al., 2009). A central issue in this context is the age of exposure. Early life stages are particularly vulnerable and disturbance of developmental processes can lead to persisting alterations in structure and function that sometimes becomes manifest only later in life. Information on early exposure to multiple chemicals can be obtained from analyses of human milk, which reflect exposure of the infant and, for chemicals with a longer half life, also provides information on prenatal exposure. We conducted an investigation of human milk in 2004, 2005 and 2006. Our goal was to compare exposure to classical persistent organic pollutants (POPs) whose levels are considered to be generally declining, with exposure to chemicals that were more recently identified as environmental pollutants and exhibit increasing production rates. The

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In Vitro and *in Vivo* Estrogenicity of UV Screens

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Ultraviolet (UV) screens are increasingly used as a result of growing concern about UV radiation and skin cancer; they are also added to cosmetics and other products for light stability. Recent data on bioaccumulation in wildlife and humans point to a need for in-depth analyses of systemic toxicology, in particular with respect to reproduction and ontogeny. We examined six frequently used UVA and UVB screens for estrogenicity *in vitro* and *in vivo*. In MCF-7 breast cancer cells, five out of six chemicals, that is, benzophenone-3 (Bp-3), homosalate (HMS), 4-methyl-benzylidene camphor (4-MBC), octyl-methoxycinnamate (OMC), and octyl-dimethyl-PABA (OD-PABA), increased cell proliferation with median effective concentrations (EC_{50}) values between 1.56 and 3.73 μM, whereas butyl-methoxydibenzoylmethane (B-MDM) was inactive. Further evidence for estrogenic activity was the induction of pS2 protein in MCF-7 cells and the blockade of the proliferative effect of 4-MBC by the estrogen antagonist ICI 182,780. In the uterotrophic assay using immature Long-Evans rats that received the chemicals for 4 days in powdered feed, uterine weight was dose-dependently increased by 4-MBC (ED_{50} 309mg/kg/day), OMC (ED_{50} 935 mg/kg/day), and weakly by Bp-3 (active at 1,525 mg/kg/day). Three compounds were inactive by the oral route in the doses tested. Dermal application of 4-MBC to immature hairless (hr/hr) rats also increased uterine weight at concentrations of 5 and 7.5% in olive oil. Our findings indicate that UV screens should be tested for endocrine activity, in view of possible long-term effects in humans and wildlife. *Key words*: benzophenone-3, estrogenic activity, MCF-7 cell proliferation, 4-methylbenzylidene camphor, octylmethoxycinnamate, pS2 protein, rat, uterotrophic assay, UV screens. *Environ Health Perspect* 109:239–244 (2001). [Online 28 February 2001] *http://ehpnet1.niehs.nih.gov/docs/2001/109p239-244schlumpf/abstract.html*

Organic chemicals that absorb UVA (400–315 nm) or UVB (315–280 nm) radiation are added in concentrations up to 10% to sunscreen products for skin protection. Some of the compounds are also included in other cosmetics such as beauty creams, lipsticks, skin lotions, hair sprays, hair dyes, shampoos, and bubble baths for product stability and durability.

Because of growing public concern about skin damage by UV light, the use of UV screens is increasing, even though the benefit with respect to prevention of melanoma remains controversial (*1,2*). Like other cosmetics such as musk fragrances (*3,4*), these chemicals are highly lipophilic and therefore can be expected to bioaccumulate in the environment. In 1991 and 1993, six different UV screens were identified in fish of the Meerfelder Maar lake (Eifel, Germany) at total concentrations of 2 mg/kg lipid in perch (summer 1991) and 0.5 mg/kg lipid in roach (1993) (*5*). Both fish species were contaminated with sunscreens, polychlorinated biphenyls and DDT at comparable levels. From these results it appeared that UV screens are relevant environmental contaminants (*5*).

Humans can be exposed to UV screens by dermal absorption (*6–9*) or through the food chain. The UV screen benzophenone-3 (Bp-3) and its metabolite 2,4-dihydroxybenzophenone have been detected in human urine from 4 hr after application of commercially available sunscreen products to the skin (*7,10*). Bp-3 has also been found to be readily absorbed from the gastrointestinal tract (*11*). Evidence for bioaccumulation in humans stems from analyses of human milk (*12*). In five out of six samples of human milk, Bp-3 and/or octyl methoxycinnamate were present in detectable amounts.

At present, the toxicologic classification of UV screens is rather heterogenous; they are classified as over-the-counter drugs in the United States, cosmetic ingredients in the European Union, and either cosmetics or quasi-drug products in Japan (*13*). Acute and subchronic systemic toxicity of these compounds is considered to be rather low (*7,14,15*), although some problems have arisen with photoallergic reactions (*16*). No values of acceptable daily intake or maximal tolerated intake of UV screens have been defined. However, the bioaccumulation potential of these lipophilic chemicals does not appear to have been considered in earlier published toxicologic long-term studies. The evidence of bioaccumulation in wildlife and humans raises the possibility of long-term exposure, including effects on reproduction and ontogeny. As a consequence, these compounds should be tested for endocrine activity.

We analyzed six frequently used UVA- or UVB-absorbing UV screens for estrogenic activity *in vitro* in MCF-7 breast cancer cells and *in vivo* in the immature rat uterotrophic assay. Estrogenic activity was demonstrated for five out of six compounds *in vitro* and for three out of six compounds *in vivo* by the oral route. The orally most active compound also increased uterine weight following dermal application.

Materials and Methods

Chemicals

The UV screens Bp-3 (2-hydroxy-4-methoxybenzophenone, oxybenzone, Eusolex 4360); butyl methoxydibenzoylmethane (B-MDM, Eusolex 9020); homosalate (HMS, 2-hydroxybenzoic acid-3,3,5-trimethylcyclohexyl ester, Eusolex HMS); 3-(4-methylbenzylidene) camphor (4-MBC, Eusolex 6300); octyl-dimethyl-*p*-aminobenzoic acid (OD-PABA, Eusolex 6007); and octyl-methoxycinnamate (OMC, Eusolex 2292) were purchased from Merck (Dietikon, Switzerland). 17β-Estradiol (E_2) and 17α-ethinylestradiol were obtained from Calbiochem (Lucerne, Switzerland), and ICI 182,780 (Astra-Zeneca) was purchased from ANAWA (Dübendorf, Switzerland).

In Vitro Studies on MCF-7 Cells

Cell line. MCF-7 human breast cancer cells (MCF7-Bos, originally from the Michigan Cancer Foundation, Detroit, MI, USA) were kindly provided by A. Soto (Tufts University, Boston, MA, USA). Cells were frozen every 10 passages. In the present experimental series, we used samples from frozen stock for a maximum of 6–13 passages. Mycoplasma status, which was regularly checked by the Institute of Virology of the Veterinary Faculty of the University of Zurich, was negative. Cells were cultured in Dulbecco's modified Eagle Medium (DME) supplemented with 5% fetal bovine serum (FBS; Gibco, Life Technologies, Basel, Switzerland) in 5% CO_2/95% air at 37°C under saturated

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Benzophenones

Ashley R. Heurung, BS,* Srihari I. Raju, MD,† and Erin M. Warshaw, MD, MS†

Abstract: **Benzophenones are ultraviolet light filters that have been documented to cause a myriad of adverse cutaneous reactions, including contact and photocontact dermatitis, contact and photocontact urticaria, and anaphylaxis. In recent years, they have become particularly well known for their ability to induce allergy and photoallergy. Topical sunscreens and other cosmetics are the sources of these allergens in most patients, but reports of reactions secondary to use of industrial products also exist. Benzophenones as a group have been named the American Contact Dermatitis Society's Allergen of the Year for 2014 to raise awareness of both allergy and photoallergy to these ubiquitous agents.**

Benzophenones are chemical ultraviolet light absorbers. They primarily absorb light in the UV-B range (290–320 nm), whereas 2 benzophenones (benzophenone-3 and benzophenone-4) also absorb UV-AII light (321–340 nm).[1] Benzophenones-1 through benzophenones-12 are substituted derivatives of 2-hydroxybenzophenone and are currently being used for a wide variety of purposes in the United States. These aromatic ketones are planar molecules that are capable of photoabsorption and resonance stabilization, which account for their ability to protect human skin and commercial products from damaging ultraviolet radiation. All benzophenones have slightly different properties based on specific molecular substitutions (Table 1).

Benzophenones were initially used as preservatives in industrial products such as paints, varnishes, and plastics to extend shelf life and reduce photodegradation. In the 1950s, benzophenones were introduced into sunscreens.[2] Although 6 different benzophenones were initially used as sunscreens, benzophenones-3, -4, -8, and -10 are now the 4 agents most commonly used in personal care products.[3] The amount of benzophenone-3 used in US sunscreens is more than all other benzophenones combined; in a 2011 study of the prevalence of known contact allergens in cosmetic and skin care products, benzophenone-3 was found in 68% of the 201 sunscreens assessed.[4] Cosmetic and toiletry products such as moisturizers, hair sprays, hair dyes, perfumes, shampoos, detergent bars, and nail polishes may also contain benzophenones. Other benzophenones continue to be used in industry, with applications ranging from incorporation into plastic lens filters for color photography, aerosol sprays to protect color prints, transparent shades to protect window displays, and many polystyrene, acrylic, and rubber products to prevent darkening and loss of structural integrity.[3]

Benzophenones have been documented to cause a myriad of adverse cutaneous reactions, including contact and photocontact dermatitis, contact and photocontact urticaria, and anaphylaxis.[5–7] In recent years, they have become particularly well known for their ability to induce allergy and photoallergy. Topical sunscreens and other cosmetics are the sources of these allergens in most patients, but reports of reactions secondary to use of industrial products also exist.

ALLERGIC CONTACT DERMATITIS

Allergic contact dermatitis to benzophenone-3 was first documented in 1972.[8] Today, it is not only the most common benzophenone to cause positive patch test reactions, but also it is the most common UV filter, overall, to cause allergy. The most recent 10-year retrospective analysis of the North American Contact Dermatitis Group Data (NACDG; 2001-2010) found that of the 219 of 23,908 patch tested patients with sunscreen listed as an allergen source, 70.2% had positive patch test reactions to benzophenone-3.[9] This finding is consistent with data from other geographic locations. Not only was benzophenone-3 the leading allergen in an Australian retrospective analysis of 6292 patients patch tested with suspicion for allergy to sunscreen, causing 28% of positive reactions,[10] but also recent European multicenter studies and a Canadian single-center study have also found benzophenone-3 to be among the most significant sunscreen allergens.[11–13]

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The effects of benzophenone-3 on apoptosis and the expression of sex hormone receptors in the frontal cortex and hippocampus of rats.

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Abstract

Benzophenone-3 (BP-3) is the most commonly used chemical UV filter. This compound can easily be absorbed through the skin and the gastrointestinal tract and can disturb sex hormone receptor function. BP-3 is lipophilic and should cross the blood-brain barrier and it may reduce the survival of neurons, although so far, its effects on nerve cells have been studied in only in vitro cultures. The aim of the present study was to determine the effects of BP-3 on apoptosis and the expression of oestrogen, androgen and arylhydrocarbon receptors (AhR) in the rat frontal cortex and hippocampus. This compound was administered dermally to female rats during pregnancy and next to their male offspring through 6 and 7 weeks of age. BP-3 in the frontal cortex induced the mitochondrial apoptosis pathway by increasing the active forms of caspase-3 and caspase-9, inducing the pro-apoptotic proteins Bax and Bak and increasing the number of cells with apoptotic DNA fragmentation. In the hippocampus, an increase in the caspase-9 level and a downward trend in the level of anti-apoptotic proteins were observed. In both brain regions, the contents of ERβ in the nuclear fraction and GPR30 in the membrane fraction were significantly reduced. BP-3 significantly increased AhR in the cytosol of the frontal cortex but had no effect on the content of this receptor in the hippocampus. This is the first study showing that exposure to BP-3 induces the mitochondrial apoptosis pathway in the rat frontal cortex and this effect may result from a weakening of the neuroprotective effects of oestrogen and/or an intensification of AhR-mediated apoptosis.

KEYWORDS: Apoptosis; Benzophenone-3; Neurotoxicity; Sunscreens

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Non-targeted metabolomics reveals alterations in liver and plasma of gilt-head bream exposed to oxybenzone.

Ziarrusta H[1], Mijangos L[2], Picart-Armada S[3], Irazola M[2], Perera-Lluna A[3], Usobiaga A[2], Prieto A[2], Etxebarria N[2], Olivares M[2], Zuloaga O[2].

Author information

Abstract

The extensive use of the organic UV filter oxybenzone has led to its ubiquitous occurrence in the aquatic environment, causing an ecotoxicological risk to biota. Although some studies reported adverse effects, such as reproductive toxicity, further research needs to be done in order to assess its molecular effects and mechanism of action. Therefore, in the present work, we investigated metabolic perturbations in juvenile gilt-head bream (Sparus aurata) exposed over 14 days via the water to oxybenzone (50 mg/L). The non-targeted analysis of brain, liver and plasma extracts was performed by means of UHPLC-qOrbitrap MS in positive and negative modes with both C18 and HILIC separation. Although there was no mortality or alterations in general physiological parameters during the experiment, and the metabolic profile of brain was not affected, the results of this study showed that oxybenzone could perturb both liver and plasma metabolome. The pathway enrichment suggested that different pathways in lipid metabolism (fatty acid elongation, α-linolenic acid metabolism, biosynthesis of unsaturated fatty acids and fatty acid metabolism) were significantly altered, as well as metabolites involved in phenylalanine and tyrosine metabolism. Overall, these changes are signs of possible oxidative stress and energy metabolism modification. Therefore, this research indicates that oxybenzone has adverse effects beyond the commonly studied hormonal activity, and demonstrates the sensitivity of metabolomics to assess molecular-level effects of emerging contaminants.

KEYWORDS: Gilt-head bream; Non-targeted metabolomics; Oxybenzone

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MeSH terms, Substances

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Oxybenzone Alters Mammary Gland Morphology in Mice Exposed During Pregnancy and Lactation.

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Author information

Abstract

Hormones and endocrine-disrupting chemicals are generally thought to have permanent "organizational" effects when exposures occur during development but not adulthood. Yet, an increasing number of studies have shown that pregnant females are disrupted by endocrine-disrupting chemical exposures, with some effects that are permanent. Here, we examined the long-term effects of exposure to oxybenzone, an estrogenic chemical found in **sunscreen** and personal care products, on the morphology of the mammary gland in mice exposed during pregnancy and lactation. Female mice were exposed to vehicle or 30, 212, or 3000 µg oxybenzone/kg/d, from pregnancy day 0 until weaning. A nulliparous group, receiving vehicle treatment, was also evaluated. Mammary glands were collected 5 weeks after involution for whole-mount, histological, immunohistochemical, and molecular analyses. Exposure to 3000 µg oxybenzone/kg/d induced permanent changes to ductal density that was significantly different from both the nulliparous and vehicle groups. The two highest doses of oxybenzone similarly induced an intermediate phenotype for expression of progesterone receptor. A monotonic, dose-dependent increase in cell proliferation was also observed in the oxybenzone-treated females, becoming statistically significant at the highest dose. Finally, oxybenzone exposure induced an intermediate phenotype for Esr1 expression in all oxybenzone-treated groups. These data suggest that oxybenzone, at doses relevant to human exposures, produces long-lasting alterations to mammary gland morphology and function. Further studies are needed to determine if exposure to this chemical during pregnancy and lactation will interfere with the known protection that pregnancy provides against breast cancer.

KEYWORDS: benzophenone; estrogen receptor; involution; parity; vulnerable period; xenoestrogen

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Free PMC Article

Natl Toxicol Program Tech Rep Ser. 2006 Feb;(533):1-264.

Toxicology and carcinogenesis studies of benzophenone (CAS No. 119-61-9) in F344/N rats and B6C3F1 mice (feed studies).

[No authors listed]

Abstract

Benzophenone is used as a photoinitiator, a fragrance enhancer, an ultraviolet curing agent, and occasionally as a flavor ingredient; it is also used in the manufacture of insecticides, agricultural chemicals, and hypnotics, antihistamines, and other pharmaceuticals; and it is used as an additive in plastics, coatings, and adhesive formulations. Benzophenone was nominated for study by the National Institute of Environmental Health Sciences based on its potential for occupational and consumer exposure and the lack of long-term toxicity data. Male and female F344/N rats and B6C3F1 mice were exposed to benzophenone (greater than 99% pure) in feed for 2 years. Genetic toxicology studies were conducted in Salmonella typhimurium, mouse bone marrow cells, and mouse peripheral blood erythrocytes. Results of 14-week toxicity studies in F344/N rats and B6C3F1 mice were reported earlier (NTP, 2000). 2-YEAR STUDY IN RATS: Groups of 50 male and 50 female rats were fed diets containing 0, 312, 625, or 1,250 ppm benzophenone (equivalent to average daily doses of approximately 15, 30, and 60 mg benzophenone/kg body weight to males and 15, 30, and 65 mg/kg to females) for 105 weeks. Survival of 1,250 ppm males was significantly less than that of controls. Mean body weights of 1,250 ppm males were markedly less than those of the controls during year 2 of the study, and weights of exposed females were consistently less than controls throughout the study. Feed consumption by 1,250 ppm males was less than that by the controls after week 70; feed consumption by 1,250 ppm females was generally less than that by the controls throughout the study. There was a positive trend in the incidences of renal tubule adenoma in males, and the incidences in 625 and 1,250 ppm males exceeded the historical control range for all routes; these neoplasms were accompanied by significantly increased incidences of renal tubule hyperplasia. Due to these findings, additional kidney sections were evaluated; results indicated additional renal tubule adenomas in all groups of males and renal tubule hyperplasia in all groups of males and females. The incidences of pelvic transitional epithelium hyperplasia and the severity of nephropathy were significantly increased in all exposed groups of male rats. Increased incidences of mononuclear cell leukemia in all exposed groups of females exceeded the historical control range from feed studies, and the incidence in 625 ppm females was significantly greater than that in the controls. Male rats exposed to 312 or 625 ppm had significantly increased incidences of mononuclear cell leukemia. One 625 ppm female and two 1,250 ppm females had histiocytic sarcomas, and the incidence in the 1,250 ppm group exceeded the range in the historical controls. Liver lesions included significantly increased incidences of hepatocytic centrilobular hypertrophy in

all exposed groups of males and females, cystic degeneration in 625 and 1,250 ppm males, and bile duct hyperplasia in all exposed groups of females. Incidences of mammary gland fibroadenoma in females exposed to 625 or 1,250 ppm were lower than expected after adjusting for body weight. 2-YEAR STUDY IN MICE: Groups of 50 male and 50 female mice were fed diets containing 0, 312, 625, or 1,250 ppm benzophenone (equivalent to average daily doses of approximately 40, 80, and 160 mg/kg body weight to males and 35, 70, and 150 mg/kg to females) for 105 weeks. Survival of all exposed groups of mice was generally similar to that of the control groups. Mean body weights of exposed females were less than vehicle controls. Feed consumption by exposed males and females was similar to that by the controls. In male mice, there were significantly increased incidences of hepatocellular adenoma in the 625 and 1,250 ppm groups, and these incidences exceeded the historical control range. All hepatocellular neoplasms combined occurred with a positive trend. In female mice, the incidences of hepatocellular adenoma in the 625 and 1,250 ppm groups were higher than expected after adjusting for the lower body weights in these groups. Incidences of centrilobular hepatocyte hypertrophy were significantly increased in all exposed groups of males and females. All exposed groups of male mice had significant increases in the incidences of multinucleated hepatocytes and chronic active inflammation. The incidences of cystic degeneration of hepatocytes in 625 and 1,250 ppm males were significantly increased. The incidence of histiocytic sarcoma in 625 ppm females was significantly increased and exceeded the historical control range. The incidences of kidney nephropathy and mineralization in exposed groups of females and the severity of nephropathy in exposed groups of males were significantly increased. The incidences of metaplasia of the olfactory epithelium were significantly increased in 1,250 ppm males and females. The incidences of hyperplasia of lymphoid follicles in the spleen were significantly increased in all exposed groups of males and in 312 and 625 ppm females.

GENETIC TOXICOLOGY: Benzophenone was not mutagenic in Salmonella typhimurium strains TA98, TA100, TA1535, or TA1537, with or without hamster or rat liver activation enzymes. No significant increases in the frequencies of micronucleated polychromatic erythrocytes were seen in bone marrow samples from male mice administered benzophenone three times by intraperitoneal injection. In addition, no increases in micronucleated normochromatic erythrocytes were noted in peripheral blood of male or female mice administered benzophenone for 14 weeks in dosed feed.

CONCLUSIONS: Under the conditions of these 2-year studies, there was some evidence of carcinogenic activity of benzophenone in male F344/N rats based on increased incidences of renal tubule adenoma; mononuclear cell leukemia in male F344/N rats may have been related to benzophenone exposure. There was equivocal evidence of carcinogenic activity of benzophenone in female F344/N rats based on the marginally increased incidences of mononuclear cell leukemia and histiocytic sarcoma. There was some evidence of carcinogenic activity of benzophenone in male B6C3F1 mice based on increased incidences of hepatocellular neoplasms, primarily adenoma. There was some evidence of carcinogenic activity of benzophenone in female B6C3F1 mice based on increased incidences of histiocytic sarcoma; the incidences of hepatocellular adenoma in female B6C3F1 mice may have been related to benzophenone exposure. Administration of benzophenone in feed resulted in increased incidences and/or severities of nonneoplastic lesions in the kidney and

liver of male and female rats and in the liver, kidney, nose, and spleen of male and female mice. Decreased incidences of mammary gland fibroadenoma in female rats were related to benzophenone exposure.

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MeSH Terms, Substances

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Joint Effects of Multiple UV Filters on Zebrafish Embryo Development

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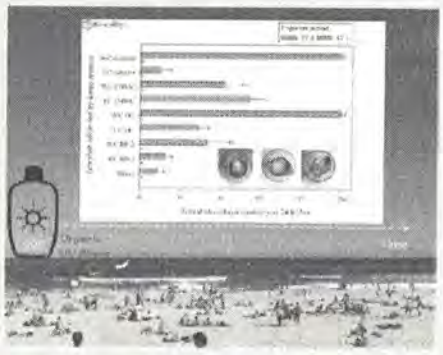
Supporting Information

ABSTRACT: The widespread use of UV filters has resulted in significant amounts of these chemicals appearing not only in the environment but also in organisms. This study first assessed the levels of nine UV filters in waters along the coast of Shenzhen, China, in tapwater, and in a nearby reservoir. UV filters were found to be high, in both winter and summer at most locations. Then, using zebrafish as a model, the influence of a UV filter mixture after dietary and aqueous exposure was assessed. After exposing artemia to three dominant UV filters at two levels and then feeding these artemia to zebrafish adults, concentrations in both were up to 4 times higher when exposed to the mixtures than when exposed to only a single UV filter. A short-term 25-day dietary exposure to the zebrafish adults did not appear to significantly influence early life stage development of the second generation; however, relatively long exposure over 47 days had significant adverse effects on embryo development. Aqueous exposure of fish embryos to mixtures of the three UV filters demonstrated a general trend of decreased heart/hatching rate as doses increased, coupled with significant changes in activities of catalase and malate dehydrogenase.



INTRODUCTION

Exposure to UV radiation, a known carcinogen, is highly associated with skin cancers and melanomas;[1] organic UV filters constitute a heterogeneous group of chemicals that, when applied to the skin, can block some of the sun's damaging UV radiation. Hence, various types of personal care products (PCPs) containing organic UV filters, such as sunscreens, skin lotions, and makeup products,[2] are widely and consistently consumed.[3] Apart from PCPs, UV filters are also present in textiles, plastics, and paints as protection against photodegradation and discoloring.[4,5]

The massive production and use of UV filters have resulted in the appearance of significant amounts of these chemicals in the environment (~6812 ng/L in water; ~10 400 ng/L in wastewater influent; ~41 610 ng/g-dw in sewage sludge)[6−10] with potential bioaccumulation in both animals (~242 ng/g-dw in fish; ~782 ng/g lipid weight in dolphin; ~3348 ng/g-dw in bird egg) and humans (~15.7 ng/mL in urine).[11−14] These chemicals are referred to as endocrine disruptors with effects reported in several in vitro and in vivo studies: median effective concentrations of benzophenone-3 (BP-3) and ethylhexyl methoxycinnamate (EHMC) were in the mg/L range for immobility of *Daphnia magna* and growth inhibition of *Raphidocelis subcapitata*.[15] BP-3 at 26 μg/L significantly affected endocrine balance and reproduction performance in Japanese medaka (*Oryzias latipes*).[16] EHMC at 394 μg/L induced significant histological changes in testes and ovaries of fathead minnows (*Pimephales promelas*).[17] Octocrylene (OC) at 383 μg/L induced alteration of 628 and 136 transcription of genes in zebrafish brain and liver, respectively, indicating influence on developmental processes, organ development, and metabolism.[18] Given the endocrine disrupting capacity of UV filters, risk assessments have been conducted using worst-case scenarios for single compounds and have concluded that the current levels of organic UV filters pose no/low risk.[7,15,19,20] Such studies, however, fail to take into consideration the possibilities (a) that interactions of environmentally relevant

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Dermatological and environmental toxicological impact of the sunscreen ingredient oxybenzone/benzophenone-3.

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Abstract

Oxybenzone (Benzophenone-3) is an emerging human and environmental contaminant used in sunscreens and personal care products to help minimize the damaging effects of ultraviolet radiation. The Center for Disease Control fourth national report on human exposure to environmental chemicals demonstrated that approximately 97% of the people tested have oxybenzone present in their urine, and independent scientists have reported various concentrations in waterways and fish worldwide. Oxybenzone can also react with chlorine, producing hazardous by-products that can concentrate in swimming pools and wastewater treatment plants. Moreover, adverse reactions could very well be increased by the closed loop of ingesting fish contaminated with oxybenzone and/or washing the ingredient off our bodies and having it return in drinking water as treatment plants do not effectively remove the chemical as part of their processing protocols. In humans, oxybenzone has been reported to produce contact and photocontact allergy reactions, implemented as a possible endocrine disruptor and has been linked to Hirschsprung's disease. Environmentally, oxybenzone has been shown to produce a variety of toxic reactions in **coral** and fish ranging from **reef** bleaching to mortality. Lastly, with the rise in skin cancer rates and the availability of more effective **sunscreen** actives such as micronized zinc oxide and titanium dioxide, serious doubts about the relative prevention benefit of personal care products containing oxybenzone must be raised and compared with the potential negative health and environmental effects caused by the accumulation of this and other chemicals in the ecosystem.

KEYWORDS: contact dermatitis; environmental contaminant; toxicity

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Chlorination and chloramination of benzophenone-3 and benzophenone-4 UV filters.

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Author information

Abstract

The objective of this research was to explore the fundamental reactions between chlorine/chloramine and 2-hydroxyl-4-methoxyl benzophenone (BP3)/2-hydroxyl-4-methoxyl benzophenone-sulfonic acid (BP4), which were the most common reactions in benzophenone-type UV filters during drinking water treatment processes. Both BP3 and BP4 could react with free chlorine and chloramine, with reactions following pseudo-first-order kinetics in excess of chlorine (HClO) and chloramine (NH_2Cl). Generally, chlorination was more rapid than chloramination. BP4 was less reactive than BP3 toward both chlorine and chloramine, due to the presence of an electron-accepting sulfonate group. Therefore, BP3 had a significantly higher disinfection by-products (DBP) formation potential than BP4. Chlorination of BP3 and BP4 generated remarkably higher levels of DBPs than chloramination, with high pH conditions facilitating the formation of chloroform but inhibiting the formation of haloacetic acid (HAAs). Comparison of the reaction behavior of two different BP-type UV filters, i.e., BP3 and BP4, revealed that certain functional groups significantly affected the reactivity of BP-type UV filters in chlorination and chloramination processes. This contribution may provide new insights into the reaction behavior of UV filters during drinking water disinfection process using chlorine and/or chloramine as disinfectant, and provide guidelines for drinking water safety management.

KEYWORDS: Benzophenone-3; Benzophenone-4; Chloramination; Chlorination; Disinfection by-products

PMID: 30077149 DOI: 10.1016/j.ecoenv.2018.07.111

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