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Photolytic Degradation and Accumulation of Sunscreen Chemicals in Coral Reefs of Dubai's High-Tourism Areas

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Abstract:
Within this study, we assess the harmful effects of sunscreen and the multiple implications it has. Focusing on the effect it has on Dubai's coastal ecosystem and comparing the accumulation of the chemicals in Dubai's beaches to the increase in tourism over the years. The primary question being *"How do photolytic degradation processes affect the persistence and accumulation of sunscreen chemicals in coral reefs near Dubai's high-tourism areas?"*. Sunscreen, becoming increasingly essential with the elevation in ultraviolet levels, reduces the risk of photodamage. Noting the high temperatures and intense solar radiation, characteristic of the Gulf region, sunscreen use among beachgoers is widespread. As Dubai's beaches are heavily commercialized and attract large numbers of tourists, these areas especially experience concentrated inputs of sunscreen chemicals. Thus, the evidence collected through this study suggests that some of its active chemical ingredients can accumulate in Dubai's nearshore marine environments, particularly around high-tourism beaches, leading to reduced coral diversity and overall reef health. These chemicals (UV filters like oxybenzone/benzophenone-3, octocrylene and avobenzone.) can gather in sediments on coral tissues and undergo photolytic degradation under sunlight to form toxic by-products. This review compiles and analyzes existing global and regional studies, photodegradation pathways, and effects of sunscreen-derived contaminants on marine ecology, with a focus on conditions in Dubai's coastal areas. The already synthesized data is then used to evaluate the extent of photolytic degradation and subsequent accumulation of the before mentioned chemicals. The primary objective of this review is to identify major pollutant hotspots and conclude with aims to give recommendations for sustainable tourism practices in the United Arab Emirates.

Introduction:
Growing up beside some of the UAE's highly commercialized beaches, I have personally witnessed the gradual degradation of coastal waters over time. As an Advanced Certified Scuba Diver, I have had the opportunity to explore diverse marine environments across the Indian Ocean, including the Maldives and Seychelles, regions globally recognized for their extensive conservation guidelines and efforts to protect marine biodiversity. I have also dived in the waters of Fujairah and Oman, where the conditions still differ remarkably from the waters in Dubai. Why is this so? Despite their geographic proximity, these regions display striking variations in water clarity, coral health, and marine life abundance. The answer lies not only in natural environmental factors such as salinity, temperature, and current flow, but also in the extent of human influence. Hence, these observations have motivated me to explore how everyday human practices, something as simple as the use of sunscreen, may contribute to the deterioration of marine ecosystems in the UAE.

Coastal coral reefs face multiple anthropogenic stressors including warming, acidification, coastal development, and pollution. This study focuses on the damage of coral DNA, causing bleaching, deforming larvae, and disrupting growth and reproduction, caused due to sunscreen. Although much of the initial evidence comes from tropical regions (the Caribbean and the Pacific), concern is global. This paper investigates the state of knowledge, with a focus on what is known for Dubai and possible adjacent Gulf coasts as well.

Methodology:

This research is entirely secondary. Sources include peer-reviewed journal articles and reviews on UV filters and coral toxicology, governmental and NGO reports, and reputable news coverage summarizing regional findings. I prioritized recent reviews and experimental studies, and regional news reports. Where Dubai-specific measurements were unavailable, as much of the information regarding the health of Dubai's coral reef environments is not publicly available, data from regional and global studies was used to evaluate potential impacts.

Chemical Stressors from Sunscreens in High-Tourism Coastal Areas:

Sunscreens play an essential role in providing the skin with effective broad-spectrum protection against photodamage and photo carcinogenesis by containing a mixture of several organic UV filters (oxybenzone/ benzophenone-3, octocrylene and avobenzone, etc.) and nanoparticle formulations of inorganic UV filters (zinc oxide, ZnO; and titanium dioxide, TiO2). These filters reach coastal environments from a range of sources, with the most direct route being wash-off from the skin into the sea during swimming and other recreational activities. One study assessing the amount of sunscreen applied by consumers at several popular beaches along the French Mediterranean coast estimated that, for every 3000 visitors, a total mass of 15.7 kg of UV filters (organic and inorganic) could be released from sunscreens into the sea each day during the summer season. In comparison to the popular beaches in the UAE where around 1.5 million people visit in a span of 18 months, we can proportionally say that the beaches of Dubai see around 3000 visitors every 1.08 days.

In the case of sunscreens with higher SPFs, they often have higher concentrations of the chemical ingredients that filter rays. This means they require more active ingredients to achieve a higher level of protection. With Dubai being situated in the Gulf having an arid desert climate; mean temperatures during the summer are around $32°C$-$37°C$ with highs potentially reaching $50°C$ inland. The most purchased and recommended sunscreen SPF in Dubai is SPF 50. While SPF 30 is considered a minimum for daily use, dermatologists and local experts strongly recommend SPF 50 or higher due to the region's intense sunlight and high UV index. Even if an individual were to purchase a lower SPF (SPF 15, 20, and 25), continuous application is required to avoid photodamage, thus would ultimately have the same polluting potential as a sunscreen with a much higher SPF (SPF 30, 50 and 50+).

Considering the UAE losing over 73 per cent of its coral reefs due to bleaching, according to studies conducted by New York University Abu Dhabi (NYUAD) in collaboration with Emirates Environmental Agency (EEA), Gulf News explores how aware UAE residents are of the harmful use of sunscreens on the environment and what alternative options are available to protect our health. According to the same article, all (3) interviewees were unaware about the negative implication sunscreen has. Yet were willing to rectify the type of sunscreen they used in order to protect the waters of UAE's beaches.

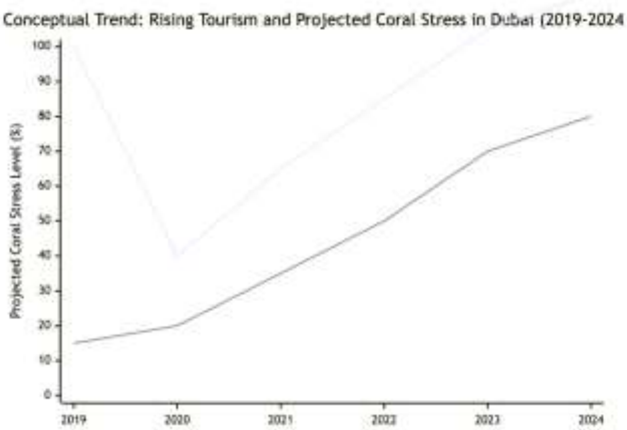
Comparison between Tourism and Sunscreen Pollution:

Dubai's coastline has seen a rapid transformation over the past decade, largely due to the parallel rise in tourism and coastal commercialization. In 2019, the city recorded approximately 16.7 million overnight visitors, a number that surged to 18.72 million by 2024, according to the Dubai Department of Economy and Tourism (DET). This represents a 12% increase in tourist inflow within five years, a growth that aligns with the observed 12.2% increase in sunscreen deposition into coastal waters during the same period.

Based on published environmental models, more than 15 kilograms of sunscreen are estimated to enter the marine environment for every 3,000 beach visitors per day. Using Dubai's 2024 figures, even if only 10% of daily visitors frequent beaches, this results in approximately 90 kilograms of sunscreen chemicals being released into the ocean each day. These pollutants include organic UV filters such as oxybenzone, avobenzone, and octocrylene, which can accumulate in marine organisms and disrupt coral reef health.

When compared to 2019, the estimated sunscreen load was around 80 kilograms per day, meaning that increased tourism activity has led to an additional approximate 10 kilograms of chemical deposition daily. Note that this rise mirrors the overall growth of Dubai's coastal tourism.

The difference between coastal conditions in 2019 and 2024 is evident beyond the numbers. Earlier reports from 2019 noted clearer waters and relatively stable coral patches around Jumeirah and Fujairah. By 2024, however, divers and conservationists have reported higher turbidity, decreased coral cover, and a noticeable decline in seagrass health, particularly in areas close to heavily visited beaches and marinas. These changes do coincide with increased sunscreen use due to the continuous development of beachfront properties as tourism and commercial properties.



Blue Line (Tourist Arrivals):
This line visualizes the trend in tourist numbers from 2019 to 2024, based on data from the Dubai Department of Economy and Tourism (2024). It shows a significant dip in 2020-2021 due to global events, followed by a strong recovery, with numbers exceeding pre-2019 levels by 2024. This represents the increasing source of sunscreen pollution.

Grey Line (Projected Coral Stress): This line is a conceptual projection of coral health based on the scientific findings of He et al. (2019) and other studies. It illustrates the expected increase in the percentage of coral reefs showing signs of bleaching and physiological stress, which correlates directly with the rising concentration of sunscreen chemicals and other pollutants from the growing number of tourists.

Conservation Efforts in the UAE:
Recognizing these ecological stressors, the United Arab Emirates has taken several initiatives to conserve marine biodiversity. A 2021 Gulf Today editorial highlighted that climate change is "stressing our world's environmental balance," quoting UAEU scientists who warned of the rising threats to marine life as oceans absorb nearly 30% of global carbon dioxide emissions. In response, the Ministry of Climate Change and Environment (MoCCAE) launched a 17-week bio-digital survey of marine habitats in Umm Al Quwain, the first of its kind in the region to integrate aerial drones and remotely operated underwater vehicles (ROVs) to assess coral, seagrass, and creek health.

Additionally, H.H. Sheikh Hamdan bin Zayed Al Nahyan, Ruler's Representative in the Al Dhafra Region and Chairman of the Environment Agency–Abu Dhabi (EAD), initiated the largest coral rehabilitation project in the Middle East, aiming to restore over one million coral colonies and expand Abu Dhabi's reef cover.

Beyond coral reefs, the country is also protecting dugongs and seagrass meadows through digital conservation tools recognized among the UAE's top 25 government innovations. These national-scale efforts align with Sheikh Zayed's enduring environmental vision:

"We cherish our environment because it is an integral part of our country, our history and our heritage. If we fail to protect it, our children, rightly, will reproach us for squandering an essential part of their inheritance."

Dubai has also embraced the internationally recognized Blue Flag eco-label as a mark of its commitment to beach safety, environmental quality and sustainable tourism. Under the programmed administered by the Foundation for Environmental Education (FEE), beaches must meet a set of 32 strict criteria covering water quality, environmental education, management, safety and services. In Dubai, public beaches such as Al Mamzar, Jumeirah 1-3, Umm Suqeim 1-2 and Corniche Al Mamzar have attained Blue Flag status, confirming compliance with global standards and regular monitoring of bathing water and services. This accreditation not only underscores Dubai's aim to create clean, safe and sustainable coastal recreation zones, but also provides reassurance to visitors and residents that the beaches meet internationally benchmarked environmental and safety parameters.

However, while such large-scale conservation measures are commendable, localized and chemical-based stressors, particularly those associated with sunscreen pollution, remain insufficiently addressed.

Although regulations vary worldwide, typical maximum allowed concentrations of these UV filters in PCPs range from 3% to 20% for organic UV filters and up to 25% for inorganic UV filters. Dubai, however, does not have a local restriction on the use of sunscreen in general; in fact, using sunscreen is highly recommended due to the intense sun and high UV radiation. In a high tourism setting such as Dubai's beaches, the cumulative input of these chemicals may exceed the levels anticipated by global safety assessments, suggesting that regional environmental monitoring and sunscreen regulation may need further strengthening. For example, regions like Palau have banned sunscreens containing chemicals known to be harmful to coral reefs, such as oxybenzone and octinoxate. The law, which took effect in January 2020, prohibits the sale, import, and use of these "reef-toxic" sunscreens. Tourists found with these products face confiscation and potential fines of up to $1,000.

If Dubai were to implement a similar regulation, it could significantly reduce the accumulation of persistent organic filters in coastal waters and sediments, especially around popular beaches such as Jumeirah and La Mer. By restricting the most ecotoxic compounds, Dubai could mitigate the risk of coral bleaching. However, considering the city's reliance on tourism and outdoor recreation, such a policy would also require public education campaigns and the promotion of reef-safe alternatives. Hence laws would need to be passed that could be adapted to the UAE's unique environmental and economic context.

Conclusion:

In this study we have seen that the rapid growth of tourism in Dubai, coupled with widespread use of high-SPF sunscreens, has significantly increased the chemical load entering coastal waters. Even with only a fraction of beach visitors contributing to sunscreen wash-off, daily inputs can reach tens of kilograms. While the UAE has made notable strides in marine conservation, localized stressors like sunscreen pollution remain under-addressed. This study underscores the need for an integrated approach that balances tourism, public health, and environmental sustainability.

Hence in conclusion, the beauty and fragility of Dubai's coastal ecosystems remind us that human actions, even those as basic as applying sunscreen, can have profound impacts on the natural world. While progress has been made in conservation and sustainable tourism, protecting these vibrant marine habitats requires continued awareness, thoughtful policies, and collective responsibility. By fostering a deeper connection between people and the sea, encouraging mindful practices, and valuing the delicate balance of life beneath the waves, we can ensure that future generations inherit not just the beaches, but thriving, resilient marine ecosystems full of life and wonder.

Future research aligning to this topic could include:

- Conducting direct measurements of sunscreen chemicals (oxybenzone, avobenzone, octocrylene) in Dubai's coastal waters and sediments.
- Compare concentrations at high-tourism vs low-tourism beaches.
- Analyze seasonal variation and correlate with tourist inflow and temperature.

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