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ORIGINAL RESEARCH ARTICLE

UV filters are an environmental threat in the Gulf of Mexico: a case study of Texas coastal zones

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Summary UV filters are the main ingredients in many cosmetics and personal care products. A significant amount of lipophilic UV filters annually enters the surface water due to large numbers of swimmers and sunbathers. The nature of these compounds cause bioaccumulation in commercial fish, particularly in estuarine areas. Consequently, biomagnification in the food chain will occur. This study estimated the amount of four common UV filters (ethylhexyl methoxycinnamate, EHMC; octocrylene, OC; butyl methoxydibenzoylmethane, BM-DBM; and benzophenone-3, BP3), which may enter surface water in the Gulf of Mexico. Our data analysis was based on the available research data and EPA standards (age classification/human body parts). The results indicated that among the 14 counties in Texas coastal zones, Nueces, with 43 beaches, has a high potential of water contamination through UV filters; EHMC: 477 kg year^{-1}; OC: 318 kg year^{-1}; BM-DBM: 258 kg year^{-1}; and BP by 159 kg year^{-1}. Refugio County, with a minimum number of beaches, indicated the lowest potential of UV filter contamination. The sensitive estuarine areas of Galveston receive a significant amount of UV filters. This article suggests action for protecting Texas estuarine areas and controlling the number of tourists and ecotourism that occurs in sensitive areas of the Gulf of Mexico.

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1. Introduction

Ultraviolet (UV) filters are common ingredients in many cosmetics and personal care products such as sunscreens, soap, shampoos, and hair sprays (Li et al., 2007; Sharifan et al., 2016; Silvia Díaz-Cruz et al., 2008). UV filters and their transformation products, which are washed off from the skin and clothes during swimming and bathing, enter the surface water (Giokas et al., 2007; Li et al., 2007; Nakajima et al., 2009; Plagellat et al., 2006; Poiger et al., 2004; Ramos et al., 2016) and are considered to be a source of surface water contamination (Ekpeghere et al., 2016; Poiger et al., 2004; Ramos et al., 2016). UV filters are added to consumer sunscreen products at different concentrations due to sunscreen formulations (Amine et al., 2012; Kupper et al., 2006; Li et al., 2007; Plagellat et al., 2006; Silvia Díaz-Cruz et al., 2008). The water contamination by UV filters is an increasing public concern due to the secondary effects (i.e. bioaccumulation) of pharmaceuticals and personal care products (PPCPs) in receiving waters, which may reach detectable and potentially toxic concentration levels (Gago-Ferrero et al., 2013; Sharifan et al., 2016).

Furthermore, due to the lipophilic characteristics of UV filters, they can bioaccumulate and biomagnify through the food chain, and their presence is associated with estrogenic effects (Broniowska et al., 2016; Mueller et al., 2003; Vila et al., 2016). Ultimately, these filters can bioaccumulate in humans (Broniowska et al., 2016; Valle-Sistac et al., 2016). Due to a high log octanol—water partition coefficient (log K_{ow}) of UV-filters (3.8—5.9), these compounds are associated with a high accumulation rate in fish (Broniowska et al., 2016; Ekpeghere et al., 2016; Kim and Choi, 2014).

Fish has a strong tendency to accumulate UV filters (Giokas et al., 2007; Liu et al., 2015). Reported concentrations of UV filters in fish ranged from 9 to 2400 ng g^{-1} lipid weight (Gago-Ferrero et al., 2015). For example, two fish species of perch and roach accumulated UV filters, respectively, by 2000 ng g^{-1} and 500 ng g^{-1} lipids (Li et al., 2007). Though the accumulation rate of UV-filters in fish has been studied both in the field and in laboratories (Blüthgen et al., 2014; Gago-Ferrero et al., 2013; Liu et al., 2015), the toxicokinetic mechanisms of these compounds in fish remain unclear.

In addition to accumulating in the food chain, UV filters have shown severe effects on coral reefs by bleaching corals at very low concentrations (Danovaro et al., 2008). Recently, the UV filters were detected at concentration levels greater than 3700 ng L^{-1} along the coastal areas of South Carolina in the USA (Bratkovics et al., 2015). This concentration may actively link to the life of U.S. endangered coral species such as *Acropora palmata* at the Flower Garden Banks National Marine Sanctuary in the northwestern Gulf of Mexico (Zimmer et al., 2006).

The long shoreline in South Texas (approximately 367 miles/590 km) is a center of recreational activities throughout the year. All 14 counties of this shoreline have 169 beaches for water activities (EPA, 2013). Every year, due to millions of beach visitors and swimmers, significant amounts of UV filters directly or indirectly (i.e. through mistreatment of wastewater, contamination of sand, etc.) enter the surface water in the Gulf of Mexico. However, UV filter concentration information is geographically restricted to some European and Asian countries, as well as Australia, whereas data from other regions, namely the Americas, is missing (Ramos et al., 2016). The potential release of these compounds has never been studied in the Gulf of Mexico. A major challenge for the potential risk effects of UV filters on aquatic life and the food chain is the availability of reliable analytical procedures that determine these substances in aquatic systems (Giokas et al., 2004, 2005; Rodil and Moeder, 2008). However, the empirical research (laboratory experiments and field surveys) is strictly limited due to financial and practical constraints (Arnot and Gobas, 2003; Korsman et al., 2015).

In order to fill the knowledge gap on the ecotoxicity of UV filters in the Gulf of Mexico region, this study aims to identify potentially hazardous substances in an effective and conservative manner. The objective of this study is to estimate the amount of UV filters: ethylhexyl methoxycinnamate (EHMC), octocrylene (OC), butyl methoxydibenzoylmethane (BM-DBM), and benzophenone-3 (BP3) entering the Gulf waters from Texas beaches.

2. Material and methods

2.1. Study area of Gulf of Mexico (Texas)

Based on an EPA report, the total number of beaches in the Texas shoreline, all 14 counties, contain 169 beaches (EPA, 2013), which are aquatic centers for swimmers and beachgoers. The counties of Nueces and Galveston have the highest number of beaches, 43 and 36, respectively. Since 1970, the population of this region increased more than 50% by 2003 based on available statistical data (Lynch et al., 2003). Texas coastal zones have the second largest number of beach visitors (3.8 million) and swimmers (3.07 million) in the entire USA (Lynch et al., 2003). Fig. 1 shows the geographical distribution of Texas counties along the Gulf of Mexico.

2.2. Chemicals

Currently, 14 organic UV filters are authorized in the USA (Ao et al., 2015; Rodil et al., 2009). Four commonly-used UV filters, which are authorized in the USA were studied herein (Santos et al., 2012; Scalia and Mezzena, 2009). The chemical structures of these four compounds, BP3, EHMC, OC and BM-DBM, are described in Table 1, which are presenting the typical structure of chemical UV filters with an aromatic moiety and a side-chain indicating different degrees of unsaturation (Silvia Díaz-Cruz et al., 2008).

2.3. Concentration of UV filters

The average content of each UV filter in cosmetic products (Table 1) was calculated as a weighted average from the composition of individual products via Eq. (1), which was developed by Poiger et al. (2004). The data of UV filter content in sunscreen products used in this study were extracted from a study by Poiger et al. (2004).

$$c_{j,\mathrm{av}} = \frac{\sum n_j c_{j,i}}{\sum n_j}. \quad (1)$$