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Review

Photocatalytic degradation of bisphenol A in aqueous media: A review

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ABSTRACT

Bisphenol A (BPA) is known to be an emerging pollutant in various environmental compartments. Human exposure to BPA occurs widely because it is commonly used as the raw material in a variety of industrial processes (e.g., the preparation of epoxy and polycarbonate resins). In this review, a brief survey was carried out to cover a range of photocatalytic materials (e.g., titania, zinc, silver, carbon, and bismuth) and their modified forms as an effective means to treat water systems contaminated with BPA. The overall efficiency and limitations of these catalysts are described for the photocatalytic treatment of BPA.

Contents

1. Introduction

Bisphenol A [BPA] is a rapidly emerging pollutant in the ambient

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environment. Three million tons of this compound are produced globally every year (Vandenberg, 2011). It has been broadly used as a raw material for the preparation of epoxy and polycarbonate resins (e.g., coatings of water containers, infant bottles, and medical devices). Because the scale of its utilization is massive, BPA contamination is found in all environmental compartments including air, water, and soil (Fu and Kayamura, 2010; Huang et al., 2012; Ritchie et al., 2013; Corrales et al., 2015) (Fig. 1). The major sources of BPA contamination in the environment are categorized as either pre- or post-consumer contamination (Fig. 1). The former is primarily due to wastes generated in the course of BPA manufacture, transport, and processing, while the latter is represented by the wastes generated upon the utilization of BPA-based products, waste water, and environmental breakdown of plastics (Corrales et al., 2015).

Considering that the utilization of BPA is projected to increase extensively, it is believed that 92% of BPA contamination is expected to exist in bodies of water. As such, it is speculated that BPA will become a major water pollutant in the future (Gavrilescu et al., 2015). To date, conventional water treatment approaches (such as chlorination and ozonation) have been unsuccessful at removing and degrading many dangerous water pollutants. Thus, many recent research efforts have been directed toward the application of photocatalysis-based treatment of BPA. The present review will provide valuable insights into the harmful impacts of BPA exposure as well as the need for the photocatalytic removal of BPA. The performance of a diverse range of potent materials (e.g., TiO_2, ZnO, Bi-/Ag-based graphene, carbon nanotubes, and their composites) will be discussed in detail. Moreover, the degradation mechanism of BPA is also described in order to demonstrate the reactivity of photocatalysts towards BPA.

2. Exposure effects on BPA on various living organisms

There are various harmful impacts of the BPA exposure onto all the living biota that includes humans. BPA is widely known for its endocrine disrupting properties in human in addition to various other harmful effects. There is a strong proven evidence that higher BPA exposure in humans could induce carcinogenesis and epigenetic modifications (Cuomo et al., 2017). Humans as well as some invertebrate species are more vulnerable to the BPA-based risks (Del Pup et al., 2015). The exposure to BPA might be affected through the multiple routes of diverse sources. For instance, according to the recent study carried out by the Jo et al. (2016), it was observed that the intake of the more than 100 g of beverages in Korean women has increased their urinary BPA levels. There is also evidence that prenatal exposure of the BPA could lead to the neurodevelopment disorders such as autism (Nor et al., 2014). On the other end, the use of polymeric baby bottles has been proven to place infants at slight risk of the BPA exposure (Moghadam et al., 2015).

As the inside of the water pipes are lined with polymers such as epoxy resins, the leaching of the BPA into water is huge concern. It is experimentally proven that hot water passage through these pipes can enhance the leaching of BPA as its potential exposure route (Rajasärkkä et al., 2016). In addition to the humans, the BPA exposure has harmful effects on aquatic organisms such as fish. For instance, the short-term exposure of the BPA at 100 mM has induced oxidative stress in the Atlantic salmon fish kidney cell line (Yazdani et al., 2016). In contrast, its long term exposure was seen to cause the transcriptional responses of the immune genes. Furthermore, the exposure at its concentrations of 50 μgl^{-1} has ability to induce harmful effect on the gill tissue of fishes (El Shaer et al., 2013). In case of invertebrates such as mice, there is evidence that the BPA exposure during gestation period has indeed exerted controls on its ambient glucose metabolism (Alonso-Magdalena et al., 2015). As such, the treated mice were found to be susceptible to diabetes based complications later on in their life. Even amongst the plants species, the BPA exposure was demonstrated to have detrimental effects. For instance, the soybean seedlings exposed to the BPA at a concentration of 1.5 mg/L has decreased the overall chlorophyll content, thereby affecting the photosynthesis of the plant (Jiao et al., 2015).

3. Conventional technologies for the BPA removal

There are various conventional approaches that have been employed in the treatment of BPA over the years. However, the overall efficiency and feasibility were constantly compromised by using conventional methods. For instance, Bourgin et al. (2013) was capable of removing the BPA samples spiked in real water (at 50 $\mu g\ L^{-1}$) in 10 min by the sodium hypochlorite (efficiency of 99%). Although there is good efficiency in the removal of BPA, there is evidence that chlorinated metabolites are formed during this process to pose some side effects (Dupuis et al., 2012). In addition to the chlorination, other methods such as advanced oxidation processes based on strong oxidizing agents (e.g., O_3 and H_2O_2) in the presence of strong UV radiation is also widely employed. Sharma et al. (2015) carried out a study in which the UV/H_2O_2 was able to remove BPA by 85% in the duration of 240 min. However, according to the studies, the UV irradiation and other experimental set up have more economic liability in addition to the formation of the

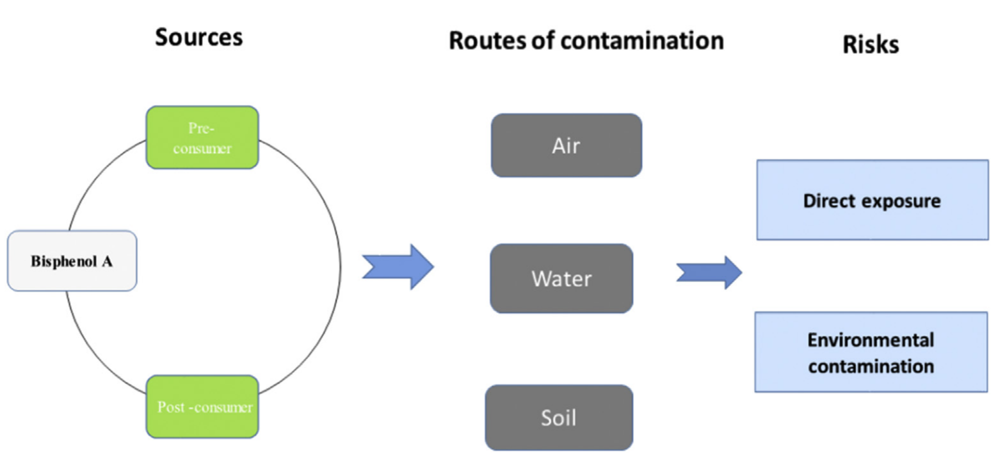

Fig. 1. Potential sources and environmental fate of BPA as an emerging environmental pollutant.