Environmental Pollution 237 (2018) 111–125

Contents lists available at ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

Bioaccumulation of organic pollutants in Indo-Pacific humpback dolphin: A review on current knowledge and future prospects

Edmond Sanganyado, Imran Rashid Rajput, Wenhua Liu*

Marine Biology Institute, Shantou University, Shantou, Guangdong Province, China

ARTICLE INFO

Article history:
Received 13 September 2017
Received in revised form
21 December 2017
Accepted 17 January 2018

Keywords:
Bioaccumulation
Sousa chinensis
Marine pollution
Emerging contaminants
Persistent organic pollutants

ABSTRACT

Indo-Pacific humpback dolphin (*Sousa chinensis*) are chronically exposed to organic pollutants since they inhabit shallow coastal waters that are often impacted by anthropogenic activities. The aim of this review was to evaluate existing knowledge on the occurrence of organic pollutants in Indo-Pacific humpback dolphins, identify knowledge gaps, and offer recommendations for future research directions. We discussed the trends in the bioaccumulation of organic pollutants in Indo-Pacific humpback dolphins focusing on sources, physicochemical properties, and usage patterns. Furthermore, we examined factors that influence bioaccumulation such as gender, age, dietary intake and tissue-specific distribution. Studies on bioaccumulation in Indo-Pacific humpback dolphin remain scarce, despite high concentrations above 13,000 ng/g lw we previously detected for PFOS, ∑PBDE and chlorinated paraffins. The maximum concentration of organochlorines detected was 157,000 ng/g wt. Furthermore, variations in bioaccumulation were shown to be caused by factors such as usage patterns and physicochemical properties of the pollutant. However, restrictions in sampling inhibit investigations on exposure pathway and toxicity of organic pollutants in Indo-Pacific humpback dolphin. We proposed the use of biopsy sampling, predictive bioaccumulation and toxicity modeling, and monitoring other emerging contaminants such as microplastics and pharmaceuticals for future health risk assessment on this critically endangered marine mammal species.

1. Introduction

Anthropogenic pollutants pose a risk to marine mammals that reside in coastal waters. Discharge of organic pollutants into marine environments has been shown to decrease water quality resulting in loss of habitats and a significant reduction in the species richness (Johnston and Roberts, 2009). The habitat loss and corresponding fragmentation often lead to isolation of marine mammal populations (Deng et al., 2016; Lai et al., 2016), and the resulting decrease in connectivity can cause population decline (Huang et al., 2012; Johnston and Roberts, 2009). Therefore, there is a need for systematic studies on the occurrence, fate, bioaccumulation and toxicity of organic pollutants in marine ecosystems.

Indo-Pacific humpback dolphins (*Sousa chinensis* Osbeck, 1765), also known as Chinese white dolphin, is a medium-sized and robust delphinid widely distributed in estuarine and inshore waters of Indian and western Pacific Ocean and also occurring along the southeastern coastal waters of China (Lin et al., 2016). Recent studies identified five fragmented colonies of this species between Xiamen and Pearl River Estuary (PRE) (Xu et al., 2015). The largest colony of <2000 dolphins dwells in the Pearl River Estuary, which receives huge amounts of organic and inorganic pollutants discharged from the Pearl River Delta, the hub of urbanization and industrialization in South Asia (Huang et al., 2012). In fact, the population of Indo-Pacific humpback dolphins is rapidly declining at an estimated annual rate of 2.46%; suggesting that by 2080, approximately 75% of the current population will be lost (Gui et al., 2017). For that reason, Indo-Pacific humpback dolphins are classified as near threatened on the IUCN Red List of Threatened Species (Lai et al., 2016).

Several studies detected POPs and pollutants of emerging concern in Indo-Pacific humpback dolphins (Gui et al., 2014a; Minh et al., 1999; Wu et al., 2013). These organic pollutants have been shown to cause adverse effects in marine mammals such as disease susceptibility, reproductive and developmental toxicity (Fig. 1) (Bossart, 2011). However, although understanding the exposure of Indo-Pacific dolphins to organic pollutants is critical in risk

* Corresponding author.
E-mail address: whliu@stu.edu.cn (W. Liu).

https://doi.org/10.1016/j.envpol.2018.01.055
0269-7491/

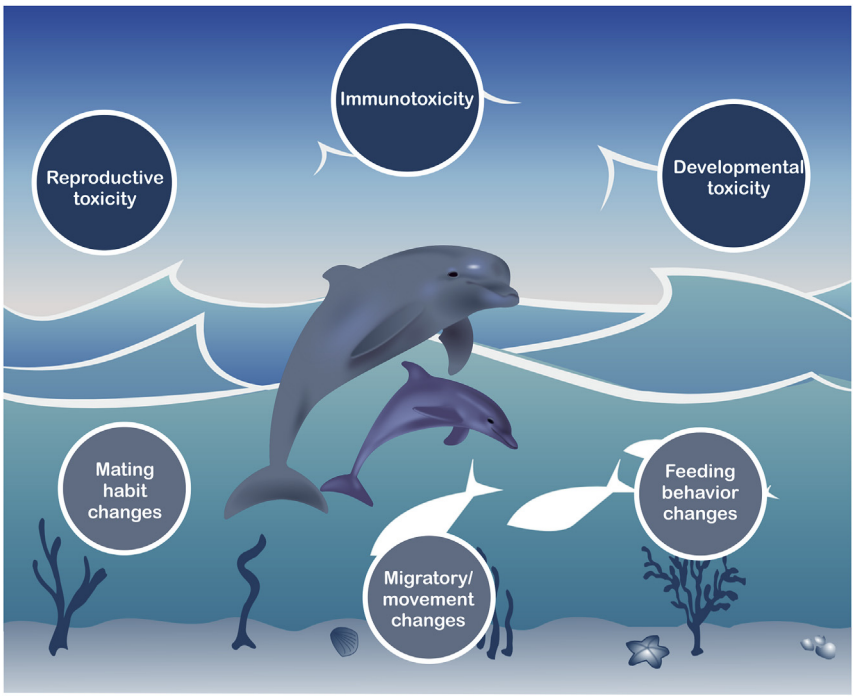

Fig. 1. Potential adverse environmental effects of exposure to organic pollutants in Indo-Pacific humpback dolphins (*Sousa chinensis*).

assessment, there are no reviews summarizing current knowledge. Hence, the aim of this paper is to critically review current data on bioaccumulation of POPs and emerging pollutants in Indo-Pacific humpback dolphin. Furthermore, we identified knowledge gaps and offered recommendation for future research direction. To put the work in context, we also reviewed the state of science regarding the health effects of organic pollutants in Indo-Pacific humpback dolphins. Using the search query "*Sousa chinensis*" on SCOPUS and ISI Web of Science, 279 research articles and reviews were identified (Fig. S1). Following manual screening, we identified 22 publications that focused on bioaccumulation of organic pollutants. However, some studies tended to report the same data twice, hence duplicate data was removed, for example, Minh et al. (1999, 2000).

In this review, we answered the following questions:

1. What are the sources and trends in the amounts of the organic pollutants in Indo-Pacific humpback dolphin?
   a. Legacy pollutants;
   b. Emerging contaminants
2. What the factors that influence bioaccumulation of organic pollutants in Indo-Pacific humpback dolphin?
   a. Intrinsic properties of the contaminant
   b. Anatomy and life history of the Indo-Pacific humpback dolphin
3. What are the knowledge gaps and suggestions for future research?

2. Regulatory frameworks for coastal marine pollution

Since the adoption of the Stockholm Convention, China continues to actively monitor organic pollutants in marine environments. In 1982, the Marine Environmental Protection Law was passed in China to protect marine ecosystems such as the PRE and it was revised in 1999 (Wang et al., 2012). Furthermore, in 2001 administrative regulations and standards were set for near coastal seawaters and technical directives were issued in 2006 (Deng et al., 2016; Tiquio et al., 2017). However, to date, no standards have been set for estuarine zones and the Ministry of Water Resources mandated a Water Management Commission for the Yangtze River and Pearl River estuaries (Deng et al., 2016).

Establishing an emission inventory of organic pollutants is critical in developing regulatory frameworks and source apportionment. In the past ten years, emissions inventories have been established for PFASs, PCBs and PCDDs. Only the usage inventories of pesticides, such as endosulfan, lindane, HCHs and chlordane have been determined at the time of writing (Liu et al., 2016). Furthermore, emissions inventory can be used to predict exposure of marine mammals to organic pollutants. However, there are no emissions inventories developed for most emerging contaminants such as halogenated flame retardants or plasticizers.

The development of effective regulatory frameworks for organic pollutants in marine environments require improvements in chemical and toxicological analysis. The knowledge of exposure to organic pollutants came through analysis of stranded Indo-Pacific humpback dolphins primarily (Gui et al., 2014a; Minh et al., 2000; Wu et al., 2013; Zeng et al., 2015). In a risk assessment study, Guo et al. (2011) observed an increase in the ecological risk of 28.7% for Indo-Pacific humpback dolphins in Xiamen coastal waters between 1996 and 2006. The change in ecological risk corresponded with the urbanization and economic development in the region (Guo et al., 2011). However, between 2006 and 2007, the ecological risk decreased by 15.7% probably due to improvements in wastewater treatment, decline in aquaculture activities and increased environmental consciousness (Guo et al., 2011).

3. Current knowledge on bioaccumulation of organic pollutants

3.1. Mechanism of bioaccumulation in marine mammals

Environmental risk of organic pollutants is often assessed by