



Assessment of marine debris in beaches or seawaters around the China Seas and coastal provinces



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ABSTRACT

Compared with United States of America (USA), Brazil, Chile, Australia, limited attention has been paid to marine debris research in China and few studies have attempted to quantify the abundance and mass of marine debris. In this study, firstly the general status and sources of marine debris in China were assessed in the time period between 2007 and 2014, and secondly marine debris situation was evaluated in three China Sea Areas (the North China Sea, the East China Sea and the South China Sea) from 2009 to 2013, and finally marine debris conditions and sources were analyzed in beaches or seawaters around some coastal provinces of China during 2007–2013. Based on above analysis, the primary conclusions were as follows: (1) The mean number and weight densities of beached marine debris (BMD) and submerged marine debris (SMD) were 4.30, 0.13 items/100 m² and 133.80, 22.60 g/100 m² in China from 2007 to 2014, respectively. The average number density of the large size FMD (LOSFMD) was 0.0024 items/100 m² and that of the small and medium size FMD (SMSFMD) was 0.30 items/100 m², and the mean weight density of the SMSFMD was 1.40 g/100 m² from 2008 to 2014. The SMD and FMD densities were at the low level and the BMD density was at the high level in China. (2) The marine debris primarily was comprised of plastic, Styrofoam, wood, glass, rubber, fabric/fiber and metal, which included almost all major categories of marine debris. (3) Sources of BMD and FMD were as follows: the first source was coastal/recreational activities, followed by other disposal sources, navigation/fishing activities and the activities related smoking, and the least source being those associated with medical/sanitary activities, while the source of SMD remained unknown. (4) The mean number and weight densities of BMD were the biggest in the North China Sea, while those of FMD and SMD were the highest in the northern South China Sea. The results of this study were beneficial to the establishment of management measures for dealing with ecological and environmental problems that were generated by the high speed socio-economic development in China.

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1. Introduction

Marine debris is defined as solid materials of human origin discarded at sea or reaching the sea through waterways (Zhou et al., 2011). It consists of various man-made wastes and can be found in almost all beaches, ocean surfaces and seafloors, even isolated islands and unpopulated coastlines (Benton, 1995; Gregory and Ryan, 1997; Haynes, 1997; Ribic et al., 1997; Convey et al., 2002; Otley and Ingham, 2003). Pollution by marine debris constitutes

a major threat to marine life (Derraik, 2002). Ingestion of plastics marine debris by seabirds, turtles and marine mammals is well acknowledged (Jantz et al., 2013; Bond et al., 2010; Lazar and Gracan, 2011; Williams et al., 2011).

Besides having significant immediate and accumulative effects on marine wildlife and biodiversity (Votier et al., 2011; Raum-Suryan et al., 2009; Carson et al., 2011; Hong et al., 2013), marine debris can cause serious environmental and economic problems, particularly in areas dependent on fishing and/or tourism (Haynes, 1997; Croxall, 1997; Huin and Croxall, 1996; Laist et al., 1999; Ballance et al., 2000; Sheavly, 2005). According to the United Nations Environment Program, “Marine litter currently poses a dire, vast and growing threat to the marine and coastal environment” (UNEP, 2011).

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In order to understand and alleviate marine debris problems, investigations of marine debris are indispensable. Marine debris includes beached marine debris (BMD), floating marine debris (FMD) and submerged marine debris (SMD). BMD is marine debris depositing on the beach, FMD is marine litters floating on the sea surface and SMD is marine debris submerging in the sea water. Therefore, surveys of marine debris include investigations of beached marine debris (BMD) (Bravo et al., 2009; Martins and Sobral, 2011; McDermid and McMullen, 2004; Rosevelt et al., 2013; Eriksson et al., 2013), floating marine debris (FMD) (Aliani et al., 2003; Thiel et al., 2003; Hinojosa and Thiel, 2009) and submerged marine debris (SMD) (Dameron et al., 2007; Bauer et al., 2008; Keller et al., 2010).

Moreover, in order to determine the transportation process, direction and the accumulation rates of marine debris, it is necessary to conduct continuous surveys at multiple sites simultaneously and grasp the variations in amount of marine debris at each site (Kataoka et al., 2012) and associated marine debris concentration (Howell et al., 2012). Consequently, it is necessary to use some new technologies and methods, such as webcam images and CIELUV (Kataoka et al., 2012), GIS-based model (Martens and Huntington, 2012), numerical models (Potemra, 2012; Lebreton et al., 2012), global set of trajectories of satellite-tracked Lagrangian drifters (Maximenko et al., 2012), to detect marine debris. At the same time, some other methods also should not be neglected. For instance, carrying out some reviews of the marine debris works (Zheng et al., 2005; Ivar do sul and Costa, 2007; Ryan et al., 2009; Gnanavel et al., 2012), initiating some incentive programs for fishermen to collect marine debris (Cho, 2009), and so on.

Compared with other countries, such as United States of America (USA), Brazil, Chile, Australia, less attention is paid to the marine debris research in China (Zhou et al., 2011). Only a few studies have been reported in the domestic literature and these studies primarily focuses on the following three aspects: (1) treatment problems of domestic waste in a small island (Chen and Chen, 2010); (2) monitoring methods, pollution investigations and potential risks of floating marine debris on marine ecological systems (Fan, 1997; Li, 2009; Su et al., 2011); (3) investigations of beached marine debris (Han et al., 2010). Few studies have attempted to quantify the abundance and mass of marine debris in China. Therefore, only limited information is available on the marine debris distribution in seawaters and beaches around China's coastal provinces.

This work aims to identify the types, quantities and sources of marine debris in China and contribute to the understanding, control and mitigation of such contaminant in the context of China's current situation of high-speed socio-economic development. Moreover, the data publication may raise the level of environmental consciousness among local citizens and beachgoers and expand their engagement activities aiming to reduce marine debris. The objectives of this article are: (1) to assess the general status and sources of marine debris in China from 2007 to 2014; (2) to evaluate marine debris situation in the three China Sea Areas (the North China Sea, the East China Sea and the South China Sea) from 2009 to 2013; (3) to analyze the status and sources of marine debris in beaches or seawaters around some coastal provinces and an autonomous region of China from 2007 to 2013.

2. Materials and methods

2.1. Study area

The study area includes the 23 coastal beaches and adjacent seawaters around the China Seas. The 23 coastal beaches and

adjacent seawaters are primarily distributed in 23 cities of Hainan Province, Guangxi Zhuang Autonomous Region, Guangdong Province, Fujian Province, Zhejiang Province, Jiangsu Province, Shandong Province, Hebei Province and Liaoning Province (Fig. 1). Based on the monitoring subarea of the beaches' environment of the National Marine Environmental Forecasting Center and Zhejiang and Fujian provinces' boundary, the 23 beaches are divided into two groups – a Northern Zone and a Southern Zone (Table 1).

Usually, the China Seas consist of the Bohai Sea, the Yellow Sea, the East Sea and the South Sea. The Bohai Sea and the Yellow Sea are often called the North China Sea. The Bohai Sea, is also known as the Bohai Gulf. Its area is approximately 78,000 km² and it has been one the busiest sea routes in recent years because of its proximity to Beijing. The Yellow Sea is located between mainland China and the Korean Peninsula and its area is about 380,000 km². The East China Sea connects with the Sea of Japan through the Korea Strait and covers an area of roughly 1,249,000 km². The South China Sea encompasses an area from the Singapore and Malacca Straits to the Strait of Taiwan of around 3,500,000 km² and its importance mainly results from one third of the world's shipping transiting through its waters.

Therefore, the three China Sea Areas include the North China Sea, the East China Sea and the South China Sea. Here, the South China Sea primarily points to its north part and is comprises of the seawaters of Guangdong Province, Guangxi Zhuang Autonomous Region and Hainan Province. The North China Sea Area includes Shandong Province, Hebei province, Tianjin Municipality and Liaoning Province. The East China Sea Area consists of Jiangsu Province, Shanghai Municipality, Zhejiang Province and Fujian Province.

In the coastal provinces, the surveyed beaches and adjacent seawaters are more than the above 23 ones. For instance, in Shandong Province, the surveyed beaches and seawaters distribute in the Dongying, Qingdao, Weifang, Rizhao, Binzhou, Weihai and Yantai City. In the different years, the surveyed beaches and seawaters may be different.

In the North China Sea, the East China Sea and the South China Sea, the investigated beaches and adjacent seawaters distribute in related several provinces and basically are same in the different years.

2.2. Study data

In China, marine debris has been monitoring since 2007. The data on types, abundance, composition and sources of marine debris in China was obtained from the Bulletins of Marine Environmental Status of China from 2007 to 2014. The information on the types, abundance and composition of marine litters in the three China Sea Areas was got from the Bulletins of Marine Environmental Status of the North China Sea, the East China Sea and the South China Sea in the time period between 2009 and 2013. The data of the types, abundance, composition and sources of marine debris for all the provinces and an autonomous region was from the bulletins of marine environmental status of corresponding provinces and autonomous region from 2007 to 2013.

2.3. Classification and sources of marine debris

Marine debris was divided into beached marine debris (BMD), floating marine debris (FMD) and submerged marine debris (SMD). FMD was further divided into the small (<2.5 cm) or medium size (≥2.5 cm and ≤10 cm) floating marine debris (SMSFMD) and the large size (>10 cm and ≤1 m) and outsize (>1 m) floating marine debris (LOSFMD).

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