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Load estimation and assessment of land-based pollution for Quanzhou Bay and their relevance to the Total Quantity Control of Pollutants Discharged into the Sea (TQCPS) Program in China

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ABSTRACT

The Total Quantity Control of Pollutants Discharged into the Sea (TQCPS) Program belonged to the Public Science and Technology Research Funds Projects of Ocean in China, launched in 2008. As one of the most important and typical demonstration cases of the TQCPS Program, a full investigation of the land-based pollutions discharges around Quanzhou Bay, China developed the total input for three main environmental factors (NH_3–N, TP, COD) which were estimated and quantified in 2008 and 2012, respectively. Combined with the trend of seawater quality changes in Quanzhou Bay in the same periods, the effects of the program's implementation were then evaluated. On the whole, by using the basic survey data and export coefficient method, the total amounts of NH_3–N, TP and COD discharged into the bay were estimated to be approximately 888.3, 130.6 and 14527.4 t/a in 2008, and 1518.6, 558.8 and 19986.7 t/a in 2012, respectively, where the percentage of the discharge from domestic sources (46.5% in 2008 and 45.2% in 2012) was generally higher than that from the other sources. Based on the characteristic of geography and administrative division, the land areas around the bay were divided into three parts: the south coast region (SCR), the west coast region (WCR), and the north coast region (NCR). The SCR and WCR accounted for 59.2 and 35.4% of the COD loads, and 49.2 and 48.0% of NH_3–N loads in 2008. The NCR contributed less of the industrial pollution, but most to domestic pollution (54.1%), followed by 26.2% in the SCR in 2012. The contributions of the discharge from different land areas to the pollution of Quanzhou Bay were found to be differed in 2008 and 2012. Due to the difference in the levels of the economic development among these three areas, the discharge of pollutants from the north coast was much lower than that from the other two parts in 2008; however, following our suggestion of the moderation and optimization of the industrial distribution and the sewage discharge around Quanzhou Bay, the contribution of the west coast decreased while that of the north coast increased significantly in 2012. Furthermore, to a great extent, because of some marine ecological rehabilitation projects, which were also suggested by our TQCPS Program and finally adopted by local government and then developed recently in Quanzhou Bay, the seawater qualities there were improved by in 2012. A longer time and greater efforts are needed to reduce the discharge of land-based pollutants and to improve the marine ecological health and sustainability further. Based on the demonstration results of the research and practice of the TQCPS Program in Quanzhou Bay, some recommendations were suggested. These require further implementation and management and can be transferred to similar estuaries and bays in southeastern coastal areas of China.

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1. Introduction

Coastal zones, such as bays and estuaries in particular, are a focus for human settlement with about 40% of the global population living within 100 km of the shoreline (SEDAC, 2011; Statham, 2012). The increasing population density, rapid socio-economic development and changes in land-use practices in past centuries have led to enhanced discharges of land-based pollutants into these coastal seawaters (Jickells, 1998; Syvitski et al., 2005; Smith et al., 2010). According to GESAMP (1986), the "environmental capacity" could be defined as "a property of the environment, a measurement of its ability to accommodate a particular activity or rate of an activity, such as discharge of contaminants, without unacceptable impact". Pollutants from land-based sources, when over its marine environmental capacity, constitute a big threat to coastal and marine ecosystems as well as the health of coastal inhabitants resulting in eutrophication (Laurence, 1992; Higashi et al., 2012), red-tide occurrence (Li and Dag, 2004), loss of biodiversity (Edinger et al., 1998), mass mortality and malformations in marine fish and benthos et al. (Williams, 1996; Islam and Tanaka, 2004). Currently, these coastal environmental problems are almost related to the input of nutrients (N, P). In conclusion, land-based pollution is recognized as one of most serious marine pollution sources worldwide contributing to more than 75% of the pollutants entering the sea (GESAMP, 1990; Goudie, 2000).

Therefore, it is very important to qualify and estimate the land-based pollutant loads which are also fundamental to the pollution control and reduction. Based on the different types of discharge, land-based pollution can be divided into point source (PS) and non-point source (NPS) pollution. PS pollution is mainly from factories and sewage treatment plants including the industrial and human wastes, while NPS pollution usually comes from precipitation, land runoff, infiltration, drainage, seepage, hydrologic modification, or atmospheric deposition (USEPA, 2003; Home et al., 2007). In the case of coastal sea water pollution, two types of NPS are of particular concern – agricultural/rural NPS and urban NPS (Ongley et al., 2010; Shen et al., 2012). Characteristically, PS pollutants can be easily distinguished, readily measured and therefore controlled through wastewater treatment facilities and industrial discharge permits etc., while NPS pollutants, carried by water moving over and through the ground, are dispersed over a large area and are much harder to measure and control (Home et al., 2007).

Since the late 1970s, there have been numerous research attempts to estimate the land-based pollution loads in coastal seas or bays around the world (Jarvie, 1997; Tuncer et al., 1998; Huang et al., 2013). Based on the research results, a series of policy instruments, such as the Total Maximum Daily Load program, Best Management Practices, the European Water Framework Directive etc., have been adopted to control the land-based pollution in developed countries such as the United States, Canada, and European Union countries. In Asia, for example in Japan, due to the worsening water quality and land-based pollution, the Law Concerning Special Measures for Conservation of the Environment of the Seto Inland Sea was enacted in 1978 (Boesch, 2002.). In 1993, the Japanese Environmental Agency established Environmental Quality Standards (EQS) and uniform national effluent standards for N and P to reduce marine eutrophication. The EQS are effective in the watershed areas of the 88 designated coastal waters (Suzuki, 2001).

In China, Chinese government has paid more and more attention to the marine environmental qualities in coastal sea area, during recent decades. In the past half century, routine monitoring of the coastal sea areas was jointly accomplished by the monitoring systems conducted by the oceanic management department and Chinese EPA, while the land-based pollution in coastal area are only condoned by the latter. Furthermore, the Station Oceanic Administration of China has carried out several national survey programs to investigate and assess the coastal environmental quality nationwide, which including the National Ocean Integrated Investigation (1958–1960), the National Coastal Zone Resource Integrated Investigation (1980–1986), the National Islands Resource Integrated Investigation (1989–1992), and the Integrated Survey and Evaluation of the Coastal Environment (2006–2011) etc. Some other large scale research programs for watershed pollution management have also been undertaken by the Ministry of Environmental Protection of China during recent decades, which including "National Programme of Action for the Marine Environment from Land-based Activities" (2006), "The First National Pollution Source Census" (2008), et al. The results of the above investigations help us understand more clearly the extent of environmental pollution in terrestrial and coastal areas in China. On the other hand, the rates of sewage treatment and emission compliance in China's coastal cities are continuously improving in recent years.

However, a large number of studies and monitoring reports have still shown that land-based inorganic plant nutrients N, P and COD has led to widespread eutrophication of offshore waters, causing water quality deterioration, aquatic ecosystem degradation, and even impairment to the socio-economic sustainable development of the coastal areas in China (e.g. Huang et al., 2003; Wu et al., 2007; Lin and Zhang, 2008; Peng et al., 2009; Zhang, 2009; Huang and Wang, 2011). Here two main reasons that might give some explanation for the current situations of coastal environmental level. On the one hand, particularly, with the developing capability of PS pollution control, there is a growing body of opinion that NPS pollution has become the significant pollution source, and this is also a particularly serious problem in China's water quality management (e.g. Song, 2000; Zhang, 2010; Chen et al., 2011). On the other hand, as shown above, the coastal sea area is a compound zone of sea-land integration, where the pollution prevention and control should be an integrated social, economic and administrative one. For the sea-land integrated regulation and control of land-based pollution in the coastal sea area, it is very important to build and maintain sustainable, and efficient monitoring methods, assessment systems, and management mechanisms. However, currently, scientific research, environmental monitoring and survey, and government management, which related to land, watershed, coast continuum and marine ecosystems, have often been separated. Actions and investments to ameliorate land-based pollution problems in the integrated river-estuary-coast system are still scarce and lag behind the above mentioned countries, despite the economic scale of investments and development that are ongoing in China (Li and Dag, 2004; Chen and Hong, 2012). In coastal areas contradictions in the roles and responsibilities among multi-sector management agencies exist due to problems with synchronous, timely investigation and joint management of land-based pollutants in China. As result, the separated environmental pollution censuses, always performed by different departments, due not matched, which means the data from different investigations cannot be combined to use for estimation of the load of the land-based pollution for the coastal bay or estuary. Due to the lack of valid estimation, any measures or actions to determine if the land–ocean interface is exceeding recommendations cannot be determined by either management department.

Fortunately, in 2008, an over-two-year-long "The First National Pollution Source Census" program, with control by The Ministry of Environmental Protection, State Statistics Bureau and Ministry of Agriculture jointly, has been successfully completed in 2010. Meanwhile, the State Oceanic Administration (SOA) of China proposed the first marine Total Quantity Control of Pollutants Discharged into the Sea (TQCPS) research program, – "The Integration