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A water quality model applied for the rivers into the Qinhuangdao coastal water in the Bohai Sea, China*

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Abstract: The water quality of all rivers into the Qinhuangdao coastal water was below the grade V in 2013. In this study, an integrated MIKE 11 water quality model is applied to deal with the water environment in the rivers into the Qinhuangdao coastal water. The model is first calibrated with the field measured chemical oxygen demand (COD) concentrations. Then the transport of the COD in the rivers into the Qinhuangdao coastal water is computed based on the model in the water environmental monitoring process. Numerical results show that the COD concentration decreases dramatically in the estuaries, from which we can determine the positions of long-term monitoring stations to monitor the river pollutions into the coastal water. Furthermore, different scenarios about the inputs of the point sources and the non-point sources are simulated to discuss the model application in the water environmental control, and simplified formula are derived for assessing the water quality and the environmental management of rivers.

Key words: water environmental management, environmental monitoring and analysis, pollution control, water quality, MIKE 11, Qinhuangdao coastal water

Introduction

The ocean is one of the most important natural resources in the economic development of coastal areas, related with, for instance, the ocean economy, including the coastal tourism, the marine communication, the transportation industry and the marine fishing industry, and it is now seen as a critical issue in China. The major ocean industries produced US\$ 2.3909×10¹¹ in the value added output in 2010 and accounted for 4.03% of China's National Gross Domestic Product^[1,2].

However, since the Industrial Revolution, in the global marine field, especially, in the coastal sea areas, the environments and the ecosystems become ever greater concerns due to the negative impacts of the urban effluent, the untreated effluent discharged into the sea, the agricultural runoff, the fishing and the shipping^[3,4]. The agricultural, industrial, and municipal discharges are the main sources of pollutants released into the coastal marine environment through rivers^[4]. The river pollutions, particularly those of the urban rivers, are one of the most serious water pollution issues of the present day^[5,6], which has great negative impacts on the quality of coastal waters. Thus, the water quality of the river into coastal waters should be taken into account in the water environmental management.

In water environmental management systems, there are various uncertainties that should be studied, such as the complicated hydrodynamic conditions, the process of the pollutant transport in the flow, and the degradation of the pollutant due to the biochemistry

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action, etc.^[7,8]. Among the accepted approaches to address these uncertainties are mathematical water quality models, to simulate the hydrodynamics and water quality transport processes^[9,10]. In the last two decades, the most frequently used water quality models are QUAL2E^[11], Delft-3D^[12], WASP^[13] and MIKE^[14]. The selection of an appropriate numerical model mainly depends on the special objectives and the characteristics of the study area. The 2-D or 3-D models, for instance, are appropriate for studying the characteristics of the estuarine and coastal waters, but for a complicated catchment system, especially in case of requiring a long-term simulation, 1-D models are more appropriate^[14,15]. MIKE 11 is a professional engineering software package for the simulation of flows, water quality and sediment transport in estuaries, rivers, irrigation systems, channels and other water bodies^[16].

the increasing terrestrial pollutant emission into the Qinhuangdao coastal area has carried excess nutrients to the coastal waters, leading to red tide outbreaks frequently in the summer^[17]. The frequently occurred extensive red tide blooms have significant negative impacts on the local bay scallop industry. It is found that about two thirds of the scallop cultivation area was affected by the blooms in 2009, and the bloom-affected area reached 3 350 km² in 2010, leading to an economic loss of RMB ¥ 2×10⁷^[18]. To minimize the loss of red tide blooms, the State Oceanic Administration of China launched a Marine Public Welfare Program, including the emergency disposal of red tide outbreaks and the total emission control of pollutants in the Qinhuangdao coastal area. The total emission control of pollutants, especially, the control of river pollutant emission into the Qinhuangdao coastal water, can optimize the environment of the coastal water, and reduce the outbreak of red tides. However, since there are no long-term continuous monitoring stations in the estuaries of rivers into the Qinhuangdao coastal water, the control of water quality is difficult.

An integrated model for the water environmental management, including the environmental monitoring and the environmental control is proposed in this study. Based on MIKE 11, a water quality model is established to determine the chemical oxygen demand (COD) transport in the rivers. Then by using the water quality model, the simulation results in the water environmental monitoring and control, including ascertaining the positions of long-term monitoring stations and controlling point sources and non-point sources pollution, are discussed. Finally, some formulas are obtained for the environmental management of rivers based on the total quantity control plan and the governance costs of point sources.

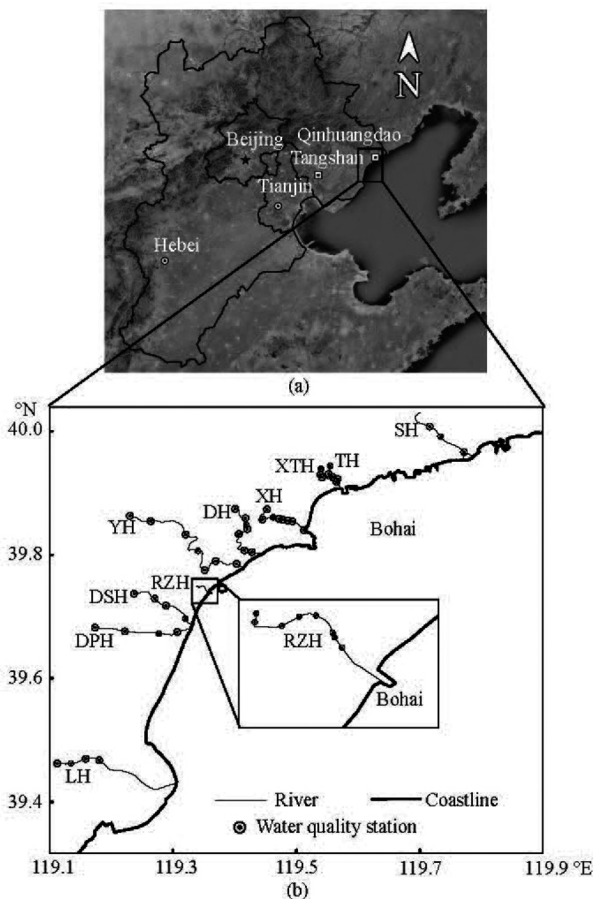


Fig.1 Geographical position of study area and water quality monitoring stations

Qinhuangdao is located in the northwest coast of the Bohai Sea and is well known as a famous summer resort (Fig.1(a)). It has a 162.7 km long coastline with many acclaimed bathing beaches for its soft fine sand and comfortable climate. However, in recent years,

1. Study area

Qinhuangdao (39°24'N-40°37'N, 118°33'E-119°51'E) is located in the northeast of Hebei Province, 280 km east of Beijing, China (Fig.1(a)), with an area of approximately 7 812 km² and a population of 2.9×10⁶. Qinhuangdao enjoys a warm semi-humid continental monsoon climate, with mean annual temperature in the range of 9°C-11°C, the highest and the lowest monthly mean temperature in the range of 23°C-25°C and -7°C-5°C, respectively^[19]. The nicest period in Qinhuangdao is from June to September (i.e., the summer) for swimming in the sea.

There are ten primary rivers cross Qinhuangdao into the coastal water, which are, respectively, Shihe River (SH), Tanghe River (TH), Xiaotanghe River (XTH), Xinhe River (XH), Daihe River (DH), Yanghe River (YH), Renzaohhe River (RZH), Dongshahe River

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