

A comprehensive research on petroleum hydrocarbon's migration processes in Jiaozhou Bay

Dongfang Yang^{1,2,3,a}, Sixi Zhu^{1,2}, Bailing Fan^{1,2}, Ming Wang^{1,2} and Xiaoye Gao^{1,2}

¹Research Center for Karst Wetland Ecology, Guizhou Minzu University, Guiyang 550025, China;

²College of Chemistry and Environmental Science, Guizhou Minzu University, Guiyang 550025, China;

³North China Sea Environmental Monitoring Center, SOA, Qingdao 266033, China.

Abstract. Petroleum hydrocarbon (PHC) pollution in marine bays has been more and more serious along with the rapid development of industry and economic, and understanding the migration processes in marine bays is essential to environmental protection. This paper provided a comprehensive research on the migration processes and laws in Jiaozhou Bay, Shandong Province of China using investigation data on 1984-1988. As a result, the annual changes of PHC contents, the changes of PHC's sources and the land-ocean migration process were defined. These findings provided solid theory basis for better understanding the transporting processes and laws of pollutants in marine bay waters.

1 Introduction

PHC is known as "black gold" and "blood of industry", is playing a very important role in modern society. However, a large amount of PHC-containing waste gas, water and residual are generating and discharging to the environment along with the rapid increase of industry and economic. Nowadays, many marine bays have been polluted by PHC since ocean if the sink of various pollutants [1-2]. Understanding the migration processes of PHC is essential to pollution control and environmental remediation in marine bays [3-4].

Jiaozhou Bay is a semi-closed bay located in south of Shandong Peninsula in eastern China, and is surrounded by cities of Jiaozhou, Jiaonan and Qingdao in the north, west and east, respectively. Previous studies showed that this bay has been polluted by various pollutants including PHC since China's Reform and Opening-up [5-6]. This paper provided a comprehensive research on the migration processes and laws in Jiaozhou Bay, Shandong Province of China using investigation data on 1984-1988. The annual changes of PHC contents, the changes of PHC's sources and the land-ocean migration process were defined, which were providing basis for environmental management decision-making.

2 Study area and data collection

Jiaozhou Bay (120°04'-120°23' E, 35°55'-36°18' N) is located in the south of Shandong Province, eastern China (Fig. 1). It is a semi-closed bay with the total area, average water depth and bay mouth width of 446 km², 7

m and 3 km, respectively. There are more than ten inflow rivers such as Haibo River, Licun River, Dagu River, and Loushan River etc., most of which have seasonal features [7-8].

Data on PHC contents in surface waters in Jiaozhou Bay was provided by North China Sea Environmental Monitoring Center. The survey was conducted in July, August and October 1984, April, July and October 1985, April, July and October 1986, May, July and November 1987, and April, July and October 1988. Surface water samples were collected and measured followed by National Specification for Marine Monitoring [9].

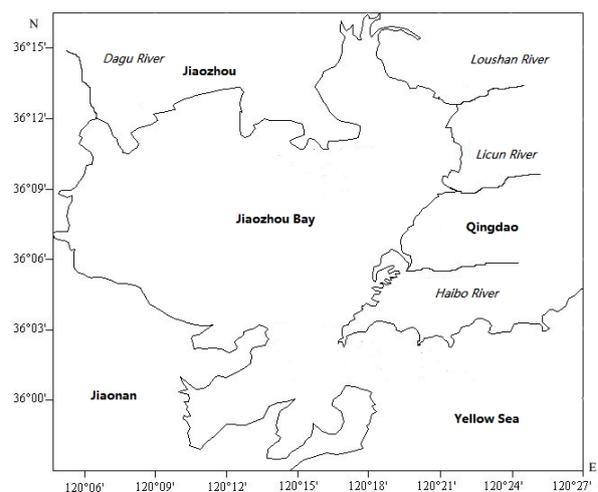


Fig. 1 Geographic location of Jiaozhou Bay

Corresponding author: dfyang_dfyang@126.com

3 Results and discussion

Annual changes of PHC's contents. In 1984, PHC's contents were ranging from 0.010-0.160 mg L⁻¹ that belong to Class I, II and III in according to Chinese Sea Water Quality Standard (GB 3097-1997) (Table 1). In 1985, PHC's contents were ranging from 0.010-0.124 mg L⁻¹ that belong to Class I, II and III. In 1986, PHC's contents were ranging from 0.005-0.122 mg L⁻¹ that belong to Class I, II and III. In 1987, PHC's contents were ranging from 0.014-0.091 mg L⁻¹ that belong to Class I, II and III. In 1988, PHC's contents were ranging from 0.005-0.178 mg L⁻¹ that belong to Class I, II and III. In general, the contamination status of PHC in Jiaozhou Bay was slight to moderate during 1984-1988, yet the contents of PHC were tending to be increasing.

Table 1 Guide lines for PHC in Chinese Sea Water Quality Standard (GB 3097-1997)

Class	I (and II)	III	IV
Guide line	0.05	0.30	0.50

Annual changes of PHC's input process. In according to the horizontal distributions of PHC's contents, the major sources could be defined, as well as the source strengths. The major source of PHC in 1984 was river discharge whose source strength was 0.050-0.160 mg L⁻¹. The major source of PHC in 1985 was river discharge whose source strength was 0.064-0.121 mg L⁻¹. The major sources of PHC in 1986 were river discharge and marine current whose source strength were 0.017-0.066 mg L⁻¹ and 0.122 mg L⁻¹. The major sources of PHC in 1987 were river discharge and marine traffic whose source strength were 0.066 mg L⁻¹ and 0.060-0.091 mg L⁻¹. The major sources of PHC in 1988 were river discharge whose source strength were 0.169-0.178 mg L⁻¹. River discharge was the major PHC's source in every year, while marine current and marine traffic were also responsible in 1986 and 1987, respectively. In general, the source strengths of river discharge were 0.017-0.178 mg L⁻¹, compared to 0.122 mg L⁻¹ and 0.060-0.091 mg L⁻¹ for marine current and marine traffic. The contribution of marine current to the source input of PHC to Jiaozhou Bay indicated that the ocean had been contaminated since 1980s due to the accumulation and storage of PHC along with the continuous source input, and the remediation of pollution in the ocean was a long-term and hard task one had been polluted. As awhile, the source input of PHC to Jiaozhou Bay was increasing and therefore pollution risk was remaining.

Land-ocean migration process of PHC's. In study area, April, May and June belong to spring, July, August and September belong to summer, October, November and December belong to autumn, and January, February and March belong to winter. In according to the seasonal distributions of PHC's contents in waters, the seasonal changes of PHC's input process could be defined. In 1984, 1985, 1986 and 1988, river discharge was the

major source, and PHC contents were in order of summer > spring > autumn in general. The reason was that the precipitation and river discharge were in order of summer > spring > autumn > winter, resulting in source input of river discharge were also in order of summer > spring > autumn > winter. However, in 1987 marine traffic was responsible, resulted in different seasonal variations of PHC in waters. By means of the continuous source input of PHC from river discharged, and the continuous accumulation of PHC in waters, a great deal of PHC was stored in Jiaozhou Bay. In case of little source input, the background value of PHC in thisbay was 0.005 mg L⁻¹, while in case of source input from marine current was responsible the high value was 0.122 mg L⁻¹. Hence, the increase of PHC contents in the ocean could be calculated as 0.122-0.005=0.117 mg L⁻¹. This was the results of the storage of PHC in ocean.

Summary of PHC's migration process. In according to the analysis on the distributions, sources and changing trends of PHC, the migration process of PHC in Jiaozhou Bay were summarized.

The major anthropogenic source input of PHC was river discharge.

2) PHC's contents in waters were mainly determined by the spatial-temporal source input from river discharge.

3) The source input of river discharge was determined by river runoff.

4) The river runoff was determined by the precipitation in study area.

5) The high value of PHC contents were tending to be increasing.

6) The pollution level of PHC during study period was slight/moderate.

7) Marine current and marine traffic were also contributing to PHC input.

8) The source input of the major sources was increasing with years.

9) PHC's contents in Jiaozhou Bay were accumulating and storing and were increasing.

10) The land-ocean migration process of PHC in Jiaozhou Bay was mainly determined by river discharge.

4 Conclusion

The migration processes in Jiaozhou Bay were analyzed and summarized. As a result, some important findings were obtained. 1) The contamination status of PHC in Jiaozhou Bay was slight to moderate, yet the contents of PHC were tending to be increasing. 2) The source input of PHC to Jiaozhou Bay was increasing and therefore pollution risk was remaining. 3) The storage of PHC in ocean resulted in an increase of PHC contents in waters as 0.117 mg L⁻¹. 4) The migration process of PHC in Jiaozhou Bay were summarized. 5) The control and management of anthropogenic input was essential.

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