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Influence of Flow Patterns on Dissolved Oxygen in Hypoxic Ports of Eutrophicated Bay Assessed by Observation and Numerical Simulation

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The coastal area at the head of Osaka Bay, which is highly urbanized, has been developed into an enclosed area with complicated artificial islands and breakwaters. In order to clarify the influence of currents on hypoxic water in this enclosed area, field surveys were done to measure currents inside the ports of Amagasaki-Nishinomiya-Ashiya and Kobe. Numerical computations to simulate currents and water quality in summertime were also carried out using the Princeton Ocean Model (POM) and a water quality model. Density current plays an important role and contributes to an increase in the current velocity and a decrease in the stagnation in the harbors. The currents in the harbors bring an increase of dissolved oxygen (DO) in the port of Kobe and a decrease of DO in the Amagasaki-Nishinomiya-Ashiya (ANA) port.

INTRODUCTION

Hypoxia, often defined as the low concentration of dissolved oxygen, is one of the main subjects of environmental research in the estuaries of Japan. Hypoxia compromises the survival of marine life and biodiversity, and its volume never decreases, in contrast with the reduction of the polluting load from land areas in recent decades. Osaka Bay is surrounded by industrially developed and highly urbanized areas. The number of people in the river basins that flow into the bay is 17 million. Most of the coastline is developed with ports, which create large sections of calm water and closed harbor spaces.

Hypoxia in Osaka Bay occurs in early summer, spreads to the head of the bay and decreases in October. In the bay's harbor, it occurs earlier and remains in November. It spreads from the ports to outside the ports. Obviously, improvement in the water quality in the harbor is a start to the improvement of the whole bay.

In this paper, field surveys have been conducted to clarify the dynamics of the water mass with low concentration of DO. One of the main surveys is to measure currents in 2 ports in the northern part of the bay. The simulation of currents and water quality using the 3D flow and water quality model were also carried out.

SETTING OF FIELD SURVEYS AND NUMERICAL SIMULATION

Outline of Survey Area

The survey area for this paper is in the northern part at the head of Osaka Bay. This is a semi-enclosed oval sea with the northeastward major axis of 60 km and the southeastward minor axis of 30 km. The bay connects with Kii Channel and the Pacific Ocean through straits of approximately 10 km and is connected to the Inland Sea through straits of 4 km. The appearance of hypoxic water in summer has taken place since 1940 as far as can be determined from old surveys (Kobe Marine Observatory, 1950). The hypoxic water mass has grown larger since 1960, when strong economic growth began (Joh, 1989).

The survey area includes the port of Amagasaki-Nishinomiya-Ashiya (ANA) and the port of Kobe (Fig. 1). From east to west, the area is 17.7-km long; it is 8.3-km wide from north to south. The survey area is largely surrounded by reclaimed land used for industrial factories and residential buildings. Harbor facilities are set along the quays of Rokko Island in the area's central section and Port Island in the western section. Port Island divides Kobe port into western and eastern parts. Lots of narrow channels have been formed between the artificial, reclaimed islands and the original land. Only small areas of the original coastline remain. The area under study is highly enclosed, with only 5 narrow open channels into and out of it. Two open channels on the south end of west Kobe port are each 250-m wide. Another channel, 0.5-km wide, is on the south end of east Kobe port; another is a 1.6-km-wide fairway between the Nishinomiya Breakwater and the No. 7 Breakwater on the south end; another, 1.4 km wide, is on the east end of ANA port. The narrowest channel, with a width of 180 m, connects west and east Kobe port, and 2 channels, with a width of 0.4 and 0.7 km, connect east Kobe port to ANA port. The water depth at ANA port is 9∼14 m, decreasing to the northward. The depth at east and west Kobe port is 9∼13 m and 8∼13 m, respectively.

The water surface area of Kobe port is of 9,200 ha, and 44,000 vessels enter the port annually carrying 96 million tons of cargo volume and trade worth 9200 billion yen. This operated cargo volume is 17% of the volume at Shanghai, the biggest port in the world, and 24% of the volume at Rotterdam.

Some small rivers flow directly into the harbor area, but the influence of freshwater from them can be ignored. However, the mouth of the Yodo River, the largest river flowing into Osaka Bay, is 3 km east from the east end of the area being studied. During periods when it discharges large amounts of freshwater, it mixes with the seawater at the east end of the port and flows into the study area.

Because this area is enclosed, the concentration of DO is very low in the port. From March to November it decreases to less than 3 mg/l on the bottom, which is the limit for bottom-dwelling creatures' survival. The concentration of Chlorophyll-a increases in summer, with the maximum value greater than 100 μg/l on the surface. Water in the ports is stratified, and a thermocline is observed very clearly.

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