

A Study on the Cause of Long-term Variations in Water Exchange and Water Quality in a Semi-enclosed Bay

Jin-Hee Yuk and Shin-ichi Aoki

Dept. of Architecture and Civil Engineering, Toyohashi University of Technology
Toyohashi, Aichi, Japan

ABSTRACT

Hamana Lake has very high closeness, chronic eutrophication and bottom hypoxia during summer. The causes of long-term variations in water exchange and water quality are discussed using the long-term data such as topographic and bathymetric changes, measurement and meteorological change over the recent 50 years. The construction of the outside jetties at the inlet led to the higher water exchange rate, which made the bottom water environment better. Since 1980, the water temperature rise associated with meteorological changes such as air temperature rise and the increase of phosphorus release flux are responsible for the deterioration of water quality.

KEY WORDS: Water exchange; water quality; jetty; water temperature; phosphorus release; Hamana Lake

INTRODUCTION

Hamana Lake is located in the middle part of Japan and connected to the Pacific Ocean through a narrow inlet (the width of inlet = 200 m), thus this lake has the very high closeness, and according to OPRF (2006), in regards to closeness Hamana Lake is in a top rank (Fig. 1). It is classified as an estuary or a coastal bay. Hamana Lake has suffered environmental issues such as eutrophication, red tide and hypoxic water. The water quality was reported to be worse especially in summer (JEMAI, 1988-1989). Chemical oxygen demand (COD) concentrations frequently exceeded the environmental standards and were reported to be on the rise.

Eutrophication does not only depend on the nutrient load but also on physical factors such as mixing and transport processes dominated by tide, river flow and winds (Ulises et al., 2005). Besides, the dynamics of the hypoxic water is determined as a result of production, transport and consumption of the oxygen caused by both physical and biochemical actions which include the transport and mixing of water by wind, tide and rainfall, and production due to photosynthesis by phytoplankton, decomposition of organisms by bacteria. In terms of physical action, environmental issues such as eutrophication and hypoxia are determined by the shape of the water body, the strength and direction of wind and water-flow, and the amount of freshwater. On the other hand, in terms of biochemical actions, those have commonly been attributed

to anthropogenic nutrient (primarily nitrogen and phosphorus) enrichment (Seliger et al., 1985; Andersen, 1997; Conley et al., 2000; Hagy and Murrell, 2007). Such environmental issues are likely to be much more significant, especially in semi-enclosed bays or estuaries with high closeness, and consequently the inevitably weak water exchange with the ocean. The weak water exchange disturbs the circulation and mixing of lake water, thus material transport becomes worse, which deteriorates the water quality in the end.

Therefore, in Hamana Lake with high closeness, chronic eutrophication and bottom hypoxia during summer, to solve such environmental problems and then to make a reasonable restoration strategy, we should understand what has impacted on the variations of the water exchange and water quality in the long view. In this study, using the long-term data such as topographic and bathymetric changes of Hamana Lake, measurement and meteorological change over about the recent 50 years (1950~2002) in Hamana Lake, we found the long-term variations and the tendency of those factors. In particular, the values during summer were employed and focused regarding measurement and meteorological data. The causes of long-term variations in water exchange and water quality was investigated and discussed on the basis of the analyses for the long-term data.

MATERIALS

The inlet of Hamana Lake had suffered the fixation of inlet width and the constructions of costal structures. Consequently, at present, the inlet width is fixed to 200 m. In addition there are a pair of jetties out of Hamana Lake inlet (west-side and east-side jetties), while a pair of jetties and a center jetty inward Hamana Lake inlet (inside west, inside east and center jetties). In the south part of Hamana Lake, there is a shallow water with mean depth of 2.5 m. As shown in Fig. 1, regarding the sudden decline of the bottom, the north part has much deeper waters than the south part, the mean depth of 7.2 m and maximum depth of 12 m. In the north part, Inohana Lake (8 % area of Hamana Lake area) and Hosoe Lake (7 % area of Hamana Lake area) lie as branch lakes. Inohana Lake is connected to the main lake through a narrow channel (minimum width = 75 m), thus this lake is doubly closed from ocean. In Hosoe Lake, Miyakoda River is situated, and among all the rivers in Hamana Lake, Miyakoda River supplies the largest freshwater. The summer averaged river discharge accounts for about 43 % of all