Effect of nitrogen and phosphorus transport from Yangtze estuary on Zhoushan coastal areas

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Abstract. There are few studies on nitrogen and phosphorus dispersion from the Yangtze estuary to adjacent Zhoushan sea areas in China. This study conducted numerical calculation to simulate the nitrogen and phosphorus transport from the Xulijujiang section of the Yangtze Estuary to Zhoushan coastal areas. The effect of inorganic nitrogen transport was greater than that of active phosphorus. The concentration increment of inorganic nitrogen near Zhoushan, Daishan and Qushan islands were between 0.5mg/L and 0.8mg/L. The concentration increment of active phosphate near Shengsi was about 0.015mg/L, and those in the coastal areas of Qushan, east Daishan and northeast Zhoushan were between 0.015-0.02mg/L. To the north of Qushan Island, the percentage of inorganic nitrogen increment to the background was more than 70%, and those of other coastal areas were about 50%. The percentage of active phosphate increase to the background was more than 70% in the north of Shengsi, and the coastal areas from Dayangshan to Qushan were more than 50%. Daishan Island, East Coastal area and east side of Shengsi accounted for 30%.

1. Introduction
The main pollutants in Yangtze estuary are nitrogen and phosphorus. According to 2016 Shanghai marine environment quality bulletin, the total nitrogen and total phosphorus from the Xuliujing section of the Yangtze River into the sea were 2180 and 104 thousand tons in 2016 [1]. During the 30 years from 1984 to 2014, the pollution of the Yangtze Estuary was serious. Most of the inorganic nitrogen and active phosphates were poorer than the Class IV sea water quality standard; the eutrophication degree of the water was high. In the 30 years, inorganic nitrogen and active phosphate were on the rise. The average values of inorganic nitrogen and active phosphate were 1.25 mg/L and 0.045 mg/L in 2005-2014[2].

These high concentration nitrogen and phosphorus would flow with the sea current, and this may have an impact on adjacent waters. Zhoushan City, Zhejiang Province is about 25km south of Yangtze estuary. According to 2016 Zhejiang marine environment quality bulletin, the pollution caused by land-based pollutants from the Yangtze River, Qiantang River and other major rivers, the main over-standard factors were inorganic nitrogen and active phosphate[3]. Thus, it is vital to clarify the pollution sources for marine environment management.

Mathematical simulation is one of the most effective ways to study the diffusion of matters. Xie et al. established a three dimensional model for Yangtze Estuary, Hangzhou Bay and the adjacent coastal
areas based on the EFDC (Environmental Fluid Dynamics Computer Code) [4]. Cao et al. used Lagrange tracer particle method to analyze the influencing factors of pollutant transport and diffusion in the Yangtze River Estuary based on the three-dimensional model. The results showed that the wind expanded the pollution area in the Yangtze River Estuary and weakened the pollution to the South shoreline of the Yangtze River Estuary and Hangzhou Bay [5]. Wang et al. tracked the movement of pollutants in three sewage outfalls of the Yangtze River Estuary, based on ECOMSED three-dimensional numerical model and Lagrange particle tracking technology. The research showed that under the joint action of runoff and tide of the Yangtze River, particles moved to the Hangzhou Bay, and the velocity was faster [6]. Liu pointed out that the water from the Yangtze River had the greatest impact on the distribution of $\text{NO}_3^-$ in Zhoushan coastal area, accounting for 50%-85%. Among the influences on the distribution of $\text{PO}_4^{3-}$ in Zhoushan coastal area, the contribution of the water from the Yangtze River in summer was about 20%-50%, and the influence of the background value was about 50%-75% [7].

There were few studies on nitrogen and phosphorus dispersion from the Yangtze estuary to Zhoushan. It is very important to clarify the effect on Zhoushan marine environment. Thus, this investigation put great emphasis on the transportation of nitrogen and phosphorus from the Yangtze River to Zhoushan.

2. Methodology

This study established a two dimensional hydrodynamic and water quality simulation model. Triangular meshes were used. The inorganic nitrogen and active phosphorus concentration from the Yangtze River into the sea were based on Xuliujing section data. The average inorganic nitrogen concentrations of Xuliujing section were obtained from the monitoring data by East China Sea Bureau of Ministry of Natural Resources in 2015-2016 (Table 1) [8]. Active phosphorus concentration of Xuliujing section used 0.060mg/L. It was the average concentration of the section in 2005-2012 [9]. The wind data was derived from the European Meso scale Meteorological Center [10].

| Time   | 2015/3 | 2015/6 | 2015/7 | 2015/8 | 2015/9 | 2015/10 | 2016/2 | 2016/5 | 2016/7 |
|--------|--------|--------|--------|--------|--------|---------|--------|--------|--------|
| Concentration | 2.02   | 1.94   | 1.51   | 1.53   | 1.71   | 1.52    | 1.77   | 1.52   | 1.68   |

| Time   | 2016/7 | 2016/8 | 2016/9 | 2016/10 |
|--------|--------|--------|--------|---------|
| Concentration | 1.68   | 1.32   | 1.30   | 1.67    |

Good agreements between the computation and the measurement of continuous tidal level, tidal current and sediment concentration of large, medium and small tides in summer of 2014 were obtained. The details of the methodology could be found in [11].

3. Results and discussion

3.1. Inorganic nitrogen and active phosphorus background concentration in Zhoushan

The measured inorganic nitrogen and active phosphorus concentration in spring were adopted as background values of Zhoushan. It can be seen that both of the two pollutants had high values in Hangzhou Bay (Figure1 and Figure 2). And it was lower in the open sea of Zhoushan. This trend conformed to the marine environment condition of Zhoushan. Inorganic nitrogen ranged from 0.39 mg/L to 1.48 mg/L; and active phosphorus ranged from 0.005 mg/L to 0.100 mg/L. Inorganic nitrogen mostly above the class IV of seawater quality standards in China (0.5mg/L). Active phosphorus was better than inorganic nitrogen, and most coastal areas were lower than the class IV of seawater quality standards in China (0.045mg/L).
Figure 1. Inorganic nitrogen background values distribution of Zhoushan City.

Figure 2. Active phosphorus background values distribution of Zhoushan City.
3.2. Inorganic nitrogen and active phosphorus increase in Zhoushan influenced by Yangtze River

This study conducted mathematical calculation to simulate the effect on inorganic nitrogen and active phosphorus in Zhoushan caused by pollution from Xuliujing section of the Yangtze Estuary. The results were analysed after the diffusion concentration kept stable (Figure 3 and Figure 4).

Under the influence of wind, the pollutants diffused from the Yangtze estuary into the adjacent coastal areas. The most influential coastal areas were Hangzhou bay. The pollutants diffused gradually into the distant Zhoushan coastal area. The effect of inorganic nitrogen was greater than that of active phosphorus.

The concentration increment near Luchaogang was about 1mg/L, which was about 0.8mg/L near Xiaoyangshan island and was between 0.5mg/L and 0.8mg/L near Zhoushan, Daishan and Qushan islands. The concentration increment of active phosphate near Luchaogang was about 0.03mg/L, and it was about 0.015mg/L near Shengsi, and was between 0.015-0.02mg/L in the coastal areas of Qushan, east Daishan and northeast Zhoushan.

3.3. The effect of the Yangtze River on Zhoushan coastal areas

The pollutants increases were compared with the background concentrations of Zhoushan (Figure 5 and Figure 6). The greatest influenced coastal area located in the north of Qushan Island, and this area had low background concentration. The percentage of inorganic nitrogen increment to the background was the greatest in the Yangtze estuary. To the north of Qushan Island, the percentage of increment was more than 70%, and that of other coastal areas was about 50%. The percentage of active phosphate increment to the background was more than 70% in the north of Shengsi, and the coastal area from Dayangshan to Qushan was more than 50%. Daishan Island, and east side of Shengsi accounted for 30%.

![Figure 3. Inorganic nitrogen increase in Zhoushan City caused by Yangtze River.](image-url)
Figure 4. Active phosphorus increase in Zhoushan City caused by Yangtze River.

Figure 5. Effect of the Yangtze estuary pollution on inorganic nitrogen in Zhoushan coastal area.
4. Conclusions
This study conducted mathematical calculation to simulate the effect on inorganic nitrogen and active phosphorus in Zhoushan caused by Xuliujing section of the Yangtze Estuary. The effect of inorganic nitrogen was greater than that of active phosphorus. The concentration increments of inorganic nitrogen near Zhoushan, Daishan and Qushan islands were between 0.5 mg/L and 0.8 mg/L. The concentration increment of active phosphate near Shengsi was about 0.015mg/L, and those in the coastal areas of Qushan, east Daishan and northeast Zhoushan were between 0.015-0.02mg/L. The greatest influenced coastal areas located in the north of Qushan Island. To the north of Qushan Island, the percentage of inorganic nitrogen increment was more than 70%, and those of other sea areas were about 50%. The percentage of active phosphate increment to the background was more than 70% in the north of Shengsi, and those for the sea area from Dayangshan to Qushan were more than 50%. Daishan Island, east Sea area and east side of Shengsi accounted for 30%.

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