Water and material budgets in the Yellow River estuary

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1. Introduction

In the previous study, Hayashi *et al.* (2004) and Hayashi *et al.* (2006), we estimated the water and nutrients budgets of the Bohai Sea in '80s and '90s and discussed the time sires variation and relation between the nutrient concentration of the Bohai Sea and the nutrient loading from the Yellow River (YR). The results are

(1) The estuary circulation and water exchange became weaken because of decreasing of the Yellow River discharge.

(2) Phosphorus loading from the Yellow River also decreases, and then the limiting nutrient for primary production is changed from nitrogen to phosphorous.

In those studies, submarine grand water (SGW) is not included. In this study, we estimate the water and phosphorus budgets including SGW by using our observation data in the project.

2. Methods

An estuary which has salinity, Si, and total phosphorus (TP) concentration, TPi, is considered as shown in Fig.1. Water, salt and TP budget are represented by the equation (1), (2) and (3), respectively, when the temporal change of salinity and TP concentration in the estuary are sufficiently smaller than the special change of there.

$$V_Q + V_P + V_G - V_E - V_R = 0 \qquad (1)$$

$$V_X S_X - V_R S_i = 0 \qquad (2)$$

$$V_Q TP_Q + V_P TP_P + V_G TP_G + V_X TP_X - V_R TP_i = 0 \qquad (3)$$

where V is the water flux, S is salinity and TP is TP concentration. And subscript Q refers the YR water, P is precipitation, G is SGW, E is evaporation, R is residual flow. Subscript X refers the water exchange, and S_X and TP_X are represented by the equation (4) and (5), respectively.

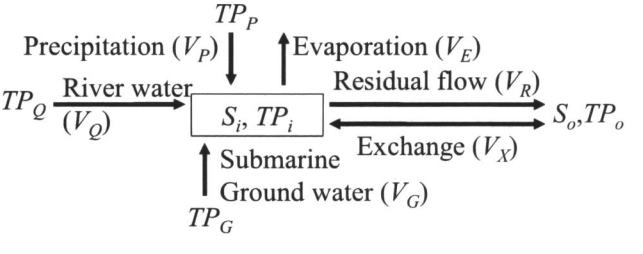

Fig.1 Water, salt and TP budgets in an estuary

$$S_X = S_o - S_i \qquad (4)$$

$$TP_X = TP_o - TP_i \qquad (5)$$

where subscript i refers the estuary and o is outside. Unknown parameters are V_R, V_X and V_G, so they are calculated by equation (1) to (3).

Moreover, advection speed, U, and diffusivity viscosity coefficient, k, are calculated by the equation (6) and (7), respectively.

$$U = V_R / F_v \qquad (6)$$

$$k = V_X L / F_v \qquad (7)$$

where F_v is the sectional area between the estuary and the outside. And residence time of the estuary water, τ_b, fresh water, τ_w, and TP, τ_{TP} are calculated by the equation (8), (9) and (10), respectively.

$$\tau_b = V_B /(V_X + |V_R|) \qquad (8)$$

$$\tau_w = (V_B \frac{S_o - S_i}{S_o}) / V_f \qquad (9)$$

$$\tau_{TP} = V_B TP_i / TP_f \qquad (10)$$

where V_B is the volume of the estuary, V_f is fresh water flux, the summation of V_Q, V_P and V_G, and TP_f is the summation of TP concentration in the fresh water.

Analyzed area is shown in Fig.2. Our observations were carried out in Sep. 2004 and May 2005. TP in grand water was not measured in Sep. 2004. Therefore we just estimated the budgets of May 2005 when the YR volume was relatively small. Salinity distribution in the sea surface in May 2005 is almost same in Sep. 2004 shown in Fig.2. And we decided the analyzed area based on the surface salinity distribution. The boundary line is ca.120 km and the average water depth is 10 m.

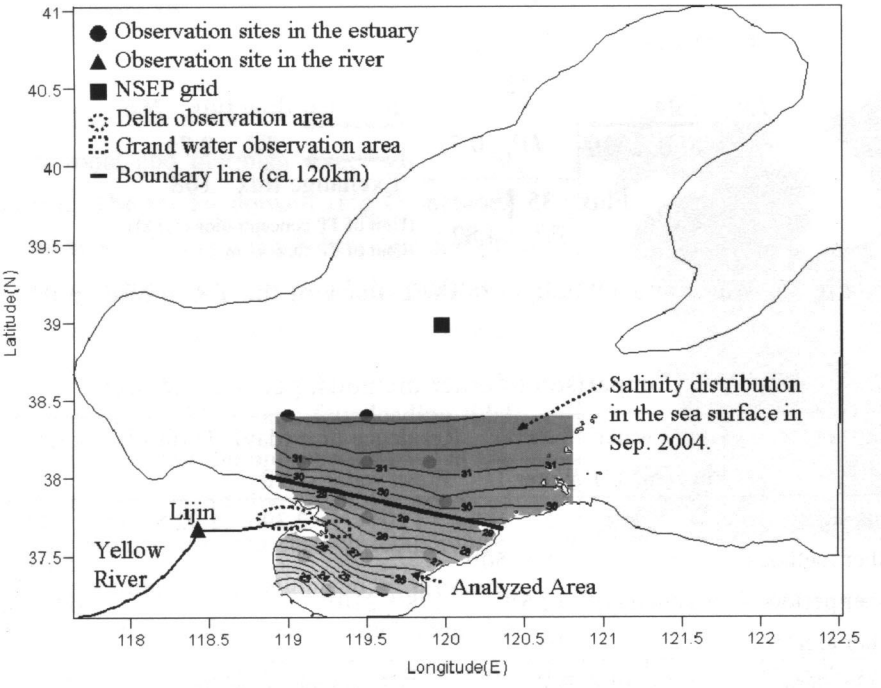

Fig. 2 Analyzed area

3. Results

Figure 3 shows the water (a) and TP (b) budget in the estuary of the YR in May 2005. Half volume of the precipitation flux is inputted from the YR. The ratio of SGW flux to the YR water flux (α) is 5 %, and that of TP flux is 10 %. The ratio of TP flux is higher than that of water flux. Because TP concentration in SGW is twice TP concentration of the YR water.

Table 1 shows other parameters, residence time, U and k of the study. Also, the comparison between other methods which is estimated in May 2005, other period, in Sep. 2004 and so on, and other area. Estimated V_G, α and k are similar to estimated values by other methods. Therefore it suggests that this estimation methods is not so bad.

References

Hayashi M. *et al.* (2004) Difference of nutrients budgets in the Bohai Sea between 1982 and 1992 related to the decrease of the Yellow River discharge. J. Korean Soc. Oceanogr., 39, 14-19.

Hayashi M. *et al.* (2006) Year-to-year Variations in the Yellow River Discharge and the Environment of the Bohai Sea. Proceedings of Techno-Ocean 2006 / 19th JASNAOE Ocean Engineering Symposium, Paper No. 162 in CD-ROM.

Taniguchi et al. (2002) Investigation of submarine groundwater discharge. Hydrol. Process., 16. 2115 2129.

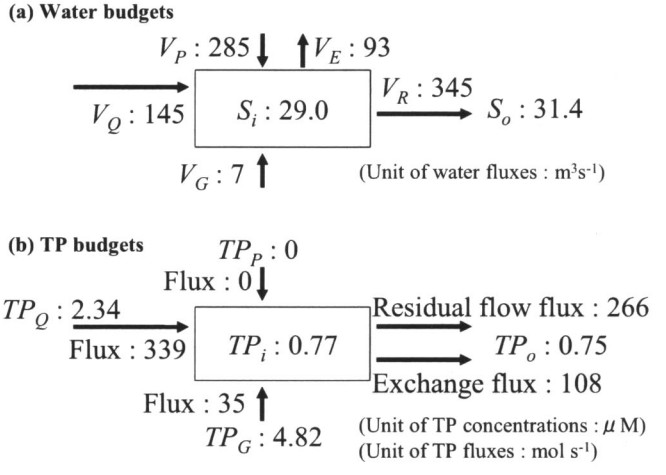

Fig.3 Water and TP budget in the estuary of the YR in May 2005

Table 1 Comparison to other methods, periods and area

Data source	Grand water	α (%)		Residence time (day)		U (m s^{-1})	k (m^2 s^{-1})
	Flux (m^3 s^{-1})	Water	TP	Fresh water	TP		
This study	7	5	10	204	2,396	1.92×10^{-4}	184
Other methods	5[1)]	5[1)]	50[1)]				58-116[2)]
Other period	(0.5-1cm/day)[3)]	12.5[4)]		128[5)], 210[5)]			180-230[2)]
Other area[6)]		10					

1) Onodera 2) Richrd & Bill 3) Taniguchi & Ishitobi
4) Lui 5) Hayashi *et. al.* (2004) 6) Taniguchi(2002)