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CALCULATIONS OF ENVIRONMENTAL CAPACITY AND POLLUTANT LOAD REDUCTION BY THE DELFT3D MODEL FOR THE DEVELOPMENT OF AQUACULTURE IN THE BACH DANG ESTUARY AREA

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ABSTRACT

This study presents the results of research on water exchange and the environmental capacities of total suspended sediment (TSS), inorganic nutrients (PO_4^{3-}, NO_3^- and NH_4^+), and heavy metals (As, Hg, Cu, Cd, Pb, and Zn) in the receiving water of the Bach Dang estuary area. The results showed that the volumes of TSS, nutrients, and heavy metals in the waters met their potential carrying capacities. During the aquaculture processes in the wet season, the TSS and NO_3^- factors polluted the water in Vietnam, with average values of 98g/m^3 and 0.081gN/m^3, respectively, while the other factors did not cause pollution in the study area. During the dry season, only the NO_3^- factor was polluted in the water body, with an average value of 0.096gN/m^3, and the other factors were not polluted in the water environment.

Keywords: Capacity, Bach Dang Estuary, TSS, Nutrients, Heavy Metals.

1. INTRODUCTION

In recent years, the water quality degradation associated with the rapid socioeconomic development in the Bach Dang estuary area, Vietnam, has attracted increasing attention from both the public and the Vietnamese government. Therefore, these types of studies are very important in estuaries that have strong interactions with rivers and sea water. For this reason, the three-dimensional Delft3D model was used to evaluate the self-purification capacity of water through the impacts of tides and sea water bodies. The major pollution in the Bach Dang estuary is dominated by domestic wastewater, industrial wastewater, agricultural wastewater and total suspended sediment (TSS) in river water. However, TSS is similar to particulates and provides attachment sites for heavy metals, such as cadmium, mercury and lead, and many toxic organic contaminants and pesticides. Therefore, the pollution factors evaluated in this study include TSS, inorganic nutrients (PO_4^{3-}, NO_3^- and NH_4^+), and heavy metals (As, Hg, Cu, Cd, Pb, and Zn).

2. METHODS

+ Delft3D model (WL | Delft Hydraulics): the numerical hydrodynamic modeling system Delft3D-FLOW can be used to solve unsteady shallow water equations in two (depth-averaged) or three dimensions. The system of equations consists of the horizontal equations of motion, the continuity equation, and the transport equations for conserved constituents (WL | Delft Hydraulics). The depth-averaged continuity equation is given by:

$$\frac{\partial\zeta}{\partial t}+\frac{1}{\sqrt{G_{\xi\xi}}\sqrt{G_{\eta\eta}}}\frac{\partial\left[(d+\zeta)U\sqrt{G_{\eta\eta}}\right]}{\partial\xi}+\frac{1}{\sqrt{G_{\xi\xi}}\sqrt{G_{\eta\eta}}}\frac{\partial\left[(d+\zeta)V\sqrt{G_{\xi\xi}}\right]}{\partial\eta}=Q$$

+ The land-ocean interactions in coastal zones (Smith et al., 1997) model is a block model used to evaluate the retention times of water bodies and the material balance, and the nutrition status in coastal water areas is applied in this model. And then average concentrations of the pollutants were calculated based on the volume of water passing through cross-sections. The material balance process in a water body can be defined using the following model:

$$\frac{dV}{dt} = \sum V_{in} - \sum V_{out} + \sum V_{sources-sinks}$$

+ Calibration and verification

In this study, we use the root mean square error (RMSE) for calibration and verification. The RMSE is calculated for the data set as follows (Chai et al., 2014):

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} e_i^2}$$

To compare the observed data and modeled shifts in the study area, we used 48-hour observation data for the TSS, phosphate and nitrate nutrients during the wet and dry seasons. On average, during the wet season, the model validation using the observed data showed fair to good TSS values of ±3.13 mg/l, which corresponded to an error of 4.48%; very good phosphate nutrient values (error ±1.645 mg/l, ~5.59%); and good NO_3^- (±17.178 mg/l, ~9.52%) and NH_4^+ (±5.8 mg/l, ~4.39%) nutrient values. On average, during the dry season, the model validation using the observed data showed fair to good TSS values of ±0.64 mg/l, with a corresponding error of ~2.39%; very good phosphate nutrient values (±5.29 mg/l, ~4.27%); and good NO_3^- (error ±2.765 mg/l, ~11.59%) and NH_4^+ (±14.862 mg/l, ~13.34%) nutrient values. Due to missing information in the heavy metal time series, we used observed data of the mean heavy metal values at 15 points in the study area.

3. RESULTS AND DISCUSSION

The calculated water quality resulted in almost all scenario simulations having high NO_3^- levels (a measure of inorganic pollution) that caused pollution in the water body, while some inorganic matter did not cause pollution. The TSS factor caused pollution during the wet season, and in almost all scenarios, the heavy metal parameters did not pollute the water body (see Table 2). Currently, the worst pollution was caused by NO_3^- nutrients (see Table 3) and.

The positive values indicate that the pollution load exceeds the environmental capacity and needs to be reduced; negative values indicate that the environmental capacity remains in surplus and can accommodate a greater pollution load. The goal was to achieve the water quality objectives under the water environment standard for aquaculture in Vietnam (QCVN).

Table 1. Modeling of ability to receive TSS mass (tons) in the area

Factors	**Dry season**		**Wet season**	
	High tide	Low tide	High tide	Low tide
Volume of area (m^3)	1633503780	1179743396	1324121700	1066303300
TSS mass in standard level	66206	53315	81675	58987
Currently TSS mass	40306	37758	154693	119968
Current ability to receive TSS	25900	15557	-73018	-60981
Ability to receive TSS in 2025	17839	8006	-103956	-84975

Table 2. Modeling of Ability to receive pollution matter in the study area (tons)

Factors	Current				In future 2025			
	Dry season		Wet season		Dry season		Wet season	
	High Tide	Low Tide	High Tide	Low Tide	High Tide	Low Tide	High Tide	Low Tide
NH_4^+	72.50	55.25	85.55	50.75	42.55	29.55	46.66	17.13
NO_3^-	-48.70	-38.58	-23.33	-34.27	-112.77	-89.86	-83.99	-86.79

PO_4^{3-}	45.87	36.66	47.69	32.11	39.01	31.00	34.78	21.63
Cu	26.79	21.34	35.02	24.51	20.32	16.01	28.03	19.07
Pb	64.88	52.23	80.09	57.72	64.22	51.69	79.30	57.08
Zn	49.94	39.97	62.39	43.88	41.80	33.30	52.75	36.32
Hg	1.19	0.96	1.47	1.04	1.13	0.90	1.38	0.98
As	6.49	5.09	8.03	4.93	3.12	2.31	3.88	1.50
Cd	6.47	5.21	7.93	5.70	6.40	5.15	7.81	5.60

Table 3. Average value modeling of some factors in the water body

Factors	QCVN	Dry season		Wet season	
		High Tide	Low Tide	High Tide	Low Tide
NH_4^+ (gN/m^3)	0.1	0.04524	0.04819	0.04763	0.05698
NO_3^- (gN/m^3)	0.06	0.09678	0.09618	0.07428	0.08904
PO_4^{3-} (gP/m^3)	0.045	0.01036	0.01062	0.01581	0.01778
Cu (g/m^3)	0.03	0.00977	0.00999	0.00856	0.00922
Pb (g/m^3)	0.05	0.00100	0.00102	0.00097	0.00108
Zn (g/m^3)	0.05	0.01229	0.01251	0.01180	0.01281
Hg (g/m^3)	0.001	0.00010	0.00010	0.00010	0.00011
As (g/m^3)	0.01	0.00510	0.00522	0.00508	0.00582
Cd (g/m^3)	0.005	0.00011	0.00012	0.00015	0.00017
TSS (g/m^3)	50	30.44	35.41	94.7	101.69

4. CONCLUSION

The reductions in TSS pollution loads required to meet the water quality targets were calculated to be 3018 tons/month during the wet season; while the necessary reductions in the NO_3^- nutrient loads were calculated to be 48.7 tons/month during the dry season and 34.27 tons/month during the wet season. For the forecasted scenario in 2025, the necessary reductions in TSS loads were calculated to be 103956 tons/month during the wet season, while the necessary reductions in NO_3^- nutrient loads were calculated to be 112.77 tons/month during the dry season and 86.79 tons/month during the wet season.

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