Environmental Assessment of Wastewater Marine Disposal of Xiaogang Zone, Ningbo

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Introduction

The Xiaogang Zonc, i. e. Ningbo Economic & Technical Development Zone, is locatcd in the northeastern part of Ningbo, China. It's area is 3. 9km^2, and it is 18km from the old urban district (see figurc). It's planned population is 50,000, and the quantity of wastewater it is designed to treat is 40,000m^3/d.

The mouth of the YongJiang Rivcr is about 600m from the zone. The average flow of the ebb tide at the river mouth is 520m^3/s, including 70m^3/s of runoff, which has a direct influence on the watcr quality of the nearby coast of the Xiaogang zone.

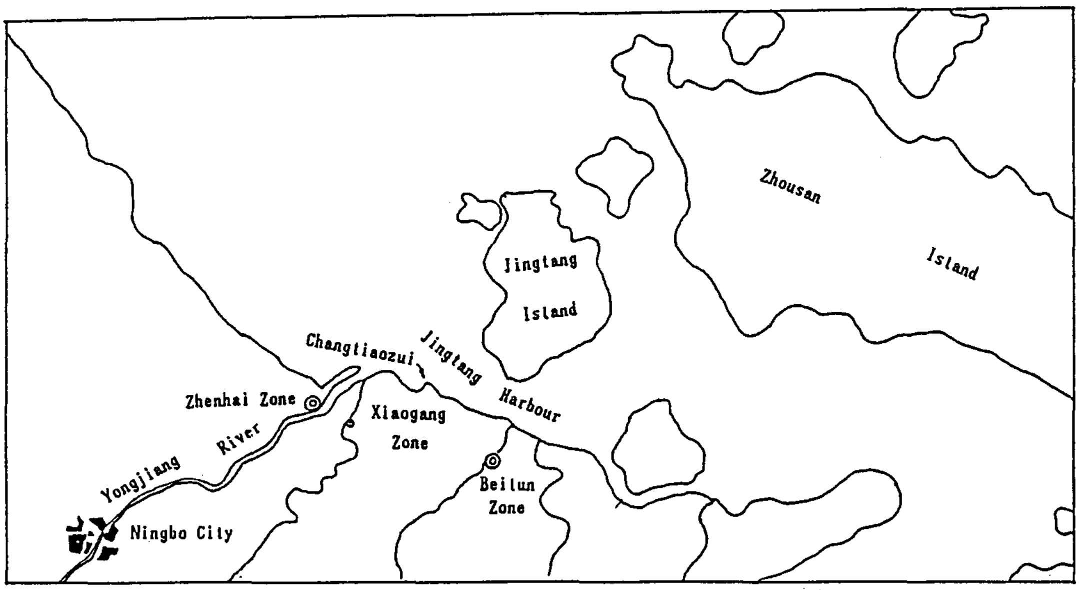

Figure. Location of the Xiaogang Zone, Ningbo, China
1 : 500,000

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The tidal flow near the Xiaogang zone is parallel to the coastlinc. There is an irregular half—day tidc. ,which takes 12.5 hours in average to occur.

In this region the difference in hcight bctwcen the high tide and cbb tide is 1.5m on average, with a maximum of 3.2m and a minimum of 0.4m. The average velocity of the rising tide and cbb tide is 0.23m/s and 0.29m/s respectively. The difference in density of sea watcr between surface and bottom is rather small. The averagc sea watcr quality in this area in winter is showm in Table1.

Table 1. Sea water quality in winter (mg/L)

Constituent / Tide	COD_{Mn} *	DO	N	P	Oil
Rising tide	3.08	8.07	1.02	0.036	0.053
Ebb tide	1.48	8.06	1.41	0.033	0.051

* in basic solution

Outlinc of Project

The flowsheet of wastewater marine disposal in the Xiaogang Zonc is shown as follows:

Wastewater→Bar rack→Pump→Microscreen→Ocean Outfall

$Q=40,000m^3/d$ ↓ $BOD_5<210mg/L$

$BOD_5 \leqslant 280mg/L$ Grit $SS<190mg/L$

$SS \leqslant 250mg/L$

The effluent from preliminary treatment is dischargcd at Changtiaozui and distributed evenly into the ocean by diffusers up to 150m offshore at a water dcpth of 15m. The diamcter of the outfall is lm, and the length of the diffuser zone is 50m. The number on diffuser ports is 11 each with diameter of 120mm . The horizontal jet velocity is 3.5m/s.

Environmental Assessment of the Project

Since the nitrogen pollution in this region is rather serious now, more consideration should be given to controlling the loss of fertilizer from the land. Therefore, in this study we usv COD_{Mn} (in basic solution) as a pollutant parameter , and we assume COD_{Mn} to be approximately equal to BOD_5. Harmful substances in industrial wastewater should be removed to meet the criteria before being discharged into sewer system.

The allowable water quality concentrations in this area can be set as follows:

$COD_{Mn} < 4mg/L \qquad DO > 4mg/L$

Basic equations:

Five mathematical models have been used in this paper.

1. Coupling solution for 1—D and 2—D pollution composition models[1]

$$\frac{\partial Z}{\partial t} + \frac{1}{B}\frac{\partial Q}{\partial x} = 0 \tag{1}$$

$$\frac{\partial Q}{\partial t} + 2u\frac{\partial Q}{\partial x} + Ag\frac{\partial Z}{\partial x} = u^2\frac{\partial A}{\partial x} - g\frac{Q|Q|}{C_z^2 AH} \tag{2}$$

$$\frac{\partial C}{\partial t} + u\frac{\partial C}{\partial x} = \frac{1}{A}\frac{\partial}{\partial x}(AE_x\frac{\partial C}{\partial x}) + P_a \tag{3}$$

$$\frac{\partial Z}{\partial t} + u\frac{\partial Z}{\partial x} + v\frac{\partial Z}{\partial y} + H\frac{\partial u}{\partial x} + H\frac{\partial v}{\partial y} = u\frac{\partial Z_0}{\partial x} + v\frac{\partial Z_0}{\partial y} \tag{4}$$

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + g\frac{\partial Z}{\partial x} = -g\frac{u\sqrt{u^2+v^2}}{C_z^2 H} + \Omega v \tag{5}$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + g\frac{\partial Z}{\partial x} = -g\frac{v\sqrt{u^2+v^2}}{C_z^2 H} - \Omega u \tag{6}$$

$$\frac{\partial C}{\partial t} + u\frac{\partial C}{\partial x} + v\frac{\partial C}{\partial y} = \frac{1}{H}[\frac{\partial}{\partial x}(HE_x\frac{\partial C}{\partial x}) + \frac{\partial}{\partial y}(HE_y\frac{\partial C}{\partial y}) + P_a(1 - K_i) \tag{7}$$

Where Z, Z_0 =altitude of water and river bed of an arbitary section

u, v =velocity component in X and Y direction

Ω =coriolis force

Cz =friction coefficient between current and river bed

H =water depth

A =cross—sectional area of river

B =river width

Ex, Ey =dispersion coefficient in X and Y direction

g =acceleration of gravity

c =pollutant concentration

Pa =intensity of source

Kt =coefficient of deoxygenation

2. Simplified two—dimension model

$$\Delta C(x,y) = \frac{P_a}{uH\sqrt{4\pi E_y x/u}} exp(-\frac{uy^2}{4E_y x}) \tag{8}$$

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where Δc=increase of pollutants by Pa in the X and Y direction

3. Water quality models developed by N. H. Brooks[2]

The initial dilution D_1 is a function of the depth Yo, the discharge—jet diameter D and the Froude number F.

The dilution due to dispersion D_2 may be found by the following equation

$$D_2 = \{erf\sqrt{\frac{3/2}{[1+\frac{2}{3}\beta(x/b)]^3-1}}\}^{-1} \quad (9)$$

4. Evaluation on alternation

The increase of pollutant concentration on X axis caused by the tide going back and forth is as follows:

$$\Delta C(x) = C_0\{erf(\psi x) + erf(\psi 3x) + [1 + erf(\psi 2x)]\sum_{k=1}^{\infty} erf(\psi KL_1)\} \quad (10)$$

where $\psi x = \sqrt{\frac{3/2}{[1+\frac{2}{3}\beta(x/b)]^3-1}}$

L_1=flow distance of a rising tide

K=alternation time

5. Trace of the particle movement

The alternation time and the trace of the particle movement can be determined by using the Euler—Lagrange method.

$$X_i(t_N) = X_i(t_{N-1}) + \int_{t_{N-1}}^{t_N} \{u_e[x_i(t_{N-1}),t]dt + \int_{t_{N-1}}^{t_N} u_e[x_i(t_{N-1}),t']dt' \cdot \nabla_N u_e[x_i(t_{N-1}),t]\}dt \quad (11)$$

where Xi=coordinate of the particle

Ue=velocity of the Eulerian field

Results

The ranges exceeding the allowable water quality concentrations by different methods are shown in Tab, 2.

Tab. 2 Ranges exceeding the allowable water quality concentrations (km^2)

Tide and season / Prediction method	Ebb tide in summer & winter	Rising tide in winter	Tidal average	Max. COD_{Mn} in water surface (mg/L)
Composition model	0. 08 (instantaneous value)	0. 34 (instantaneous value)	0. 06	5. 5
Simplified twodimension model	0. 01	0. 02	—	4. 2
Model of Brooks with consideration of alternation	0. 023	0. 077	—	6. 0

The times and percentages of discharged sewage particle leaving the water area considered during different tidal periods are calculaied by equation(11)(Table 3).

Table 3. Times and percentages of particle leaving the water area

	Time (h)	Percentage of paricle (%)	Time (h)	Percentage of particle (%)
At begining of rising tide	3	80	32	20
At rapid rising tide	2	40	36	60
At the end of rising tide	4	80	5	20
At rapid ebb tide	2	100	0	0

From Table 3 we can see that all discharged particles will leave the water area considered after 3 tidal periods.

Based on the analyses in the environmental assessment mentioned above, we consider that the design of the project is acceptable.

References

1. Han Z. , Chen H. , Geng Z. Coupling Solution for 1—D and 2—D Pollution Composition Model, 6th Congress of Asia & Pacific Regional Division, I. A. H. R. Kyoto, Japan, July 1988.

2. Fischer H. B. , Imberger J. , list E. J. , Brooks N. H. , Mixing in Inland and Coastal Wsters, 1979.

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