Journal of Environmental Sciences Vol. 9, No. 4, pp. 454—462, 1997 ISSN 1001—0742

Sewage draining schemes of Qinhuangdao City in Beidaihe Area, China

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Abstract—On the basis of field investigation and exploration survey, oceanic environment influence of all kinds of sewage sea draining schemes in Beidaihe Area was forecasted and evaluated. Construction scheme of deepsea draining with first-order disposal was selected through comprehensive analysis comparison of oceanic environment benefit and engineering economic results. This scheme has been adopted by construction units.

Keywords: sewage disposal; deepsea draining; numerical simulation; environment benefit.

Qinhuangdao City is one of the first-group of open to out coastal cities in China, with long history, beautiful Beidaihe River seashore, old Shanhaiguan City, beginning point of the Great Wall Laolongkou and the wide seaside resort with soft sand and flat tidal shallow. All these make the city to be one of the most famous tourist cities in the world. Beidaihe Area was determined to be the work place and sanatorium for the party and national organization in 1982.

With the quick development of industry and tourism in Qinhuangdao City, sewage amount of the city increases continualy. Pollution of the city environment and costal oceanic environment have been caused because sewage directly drains into Daihe, Yanghe and the coastal sea without disposal. The government of Qinhuangdao City decided to construct Beidaihe sewage disposal engineering in order to protect tourist resource and promote tourist cause and to develop the economic construction continuously.

Generally, there are two ways in sewage disposal of coastal cities. One is that sewage is drained into the sea fairly far away from the shore through the transport of seafloor pipe line after first-order disposal or predisposal, this is called deepsea drainage. The other way is that sewage is drained into the river or drained near the shore after second-order disposal. Whichever way to be applied, sewage after treatment should be drained into the sea. Government of Qinhuangdao City entrusted the first institute of oceanography, SOA, Qingdao to suggest draining plans for sewage in Beidaihe Area.

The basic method of this research is as follows: first, current quality situation of coastal oceanic environment, oceanic function division of sea area accepted sewage and sea water quality standard were made clear through field investigation; then based on the examined values and data

of current and tidal level which were collected in the study sea area, mathematical models of current field and pollutant transport and dispersion were set up and the mixture region area (expressed by COD factor) of preselected sewage outlet at different disposal degree and different disposal scale was calculated; then path of movement and dispersion of polluted water mass and movement and dispersion law of examined polluted sediment were forecasted. At last, practical sewage draining plan was selected through comprehensive analysis and comparison of engineering economic results of every kind of sewage draining plan and oceanic environment influence.

1 Investigation research of current environment quality situation of sea accepted sewage

Sewage disposal plant site and environment protection target of sea area accepted sewage in Beidaihe Area are shown in Fig. 1. United investigation of sea water, sea sediment and ocean ecology were taken in the study area. The results showed that current oceanic environment quality situation basically accorded with type I sea water quality standard, but large intestine bacterial group and COD pollution existed in offshore bathing beach. Large intestine bacterial group in some bathing beach can reach 24000 per liter and COD_{Mn} can reach 6 mg/L, this largely exceeds the given values in type I sea water quality standard (large intestine group 10000/L, COD_{Mn} 3 mg/L). Sea sediment quality basically is in good state and ecologic environment quality still belongs to normal state. Sea water pollution in offshore bathing beach resulted from direct drainage of sewage without treatment in Beidaihe Area and one part of unperfect sewage pipe nets. We can know the necessity to build sewage disposal plant engineering in Beidaihe Area from the above statement.

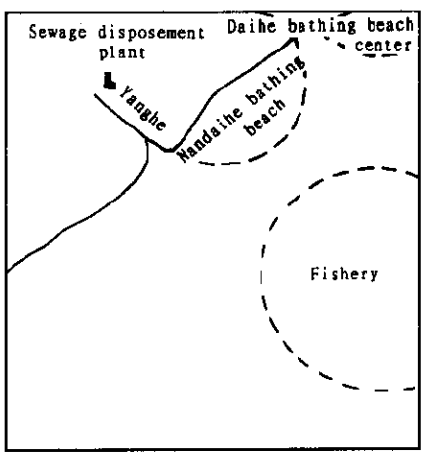

Fig. 1 Sewage disposal plant and environment protection target

2 Coastal oceanic function division in Beidaihe Area

According to the stipulation of Feihai pledge (1995) number 022 file of ocean bureau in Hebei Province, it is coastal line of bathing beach and tourist live in coastal sea region of Beidaihe and type II sea water quality standard is carried on. Considering that sewage raining sea area is fairly near to several important bathing beaches of Beidaihe Seaside beach, environment protection policy and countermeasure should be proposed according to type I sea water quality required by Qinhuai pledge (1996) number 76 file of environment protection bureau in Qinhuangdao City in order to guarantee the safety of these bathing beaches.

3 Numerical simulation of coastal tidal current field in Beidaihe

Two dimension tidal current numerical model and ADI method were applied to calculate the current field in the study sea region.

Differential equation of two dimension tidal current mathematical model is as follows:

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + V\frac{\partial u}{\partial y} - fV + g\frac{\partial \zeta}{\partial x} + \frac{gu\sqrt{u^2 + V^2}}{C^2(H + \zeta)} = 0,$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + V\frac{\partial v}{\partial y} - fu + g\frac{\partial \zeta}{\partial y} + \frac{gv\sqrt{u^2 + V^2}}{C^2(H + \zeta)} = 0,$$

$$\frac{\partial \zeta}{\partial t} + \frac{\partial}{\partial x}[(H + \zeta)u] + \frac{\partial}{\partial y}[(H + \zeta)v] - 0.$$

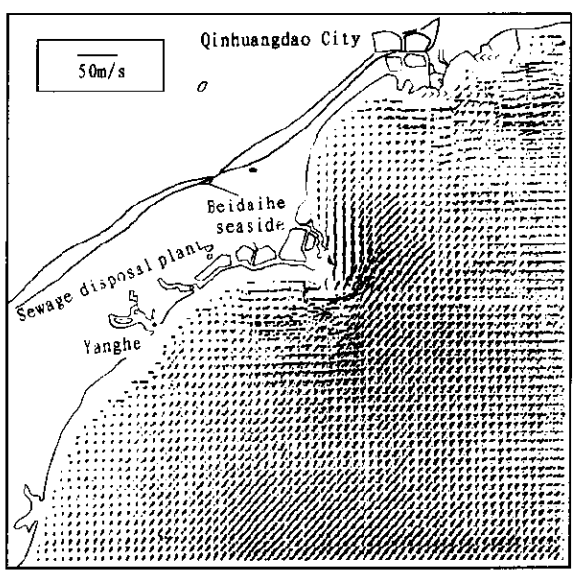

Fig. 2 Simulated tidal current field graph (at outgoing tide)

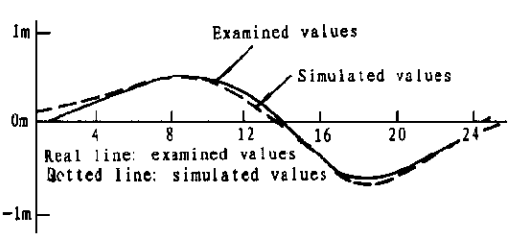

Fig. 3 Tidal level verification graph

Where, u, V *are the* x, y components of velocity; H is the water depth from sea surface; ζ is the water level from sea surface; C is the Xiecai coefficient; F is the Coriolis coefficient; G is the gravity acceleration; Space step size: $\triangle s = 500$m.

Simulated results of tidal current field (at outgoing tide) is shown in Fig. 2. It was determied that current field model accorded well with examined results. Fig. 3 is the tidal level verification graph and Fig. 4 is the verification curve of tidal current, respectively.

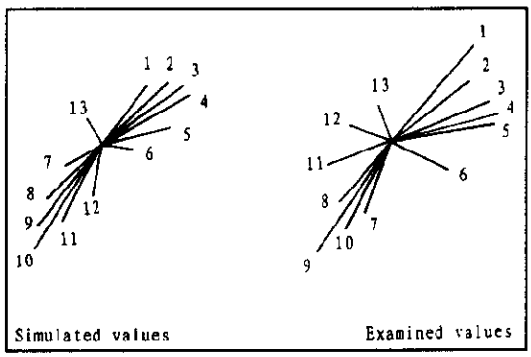

Fig. 4 Tidal current verification graph

4 Study on pollutant transport and dispersion law in preselected sewage draining outlet

4.1 Location of every preselected sewage draining outlet

Some related departments have raised two sewage sea draining pipe lines one after another from 1992. We suggested to adopt the third sewage pipe line in 1996. Trends of every sewage draining pipeline and location of every preselected sewage draining outlet are shown in Fig.5.

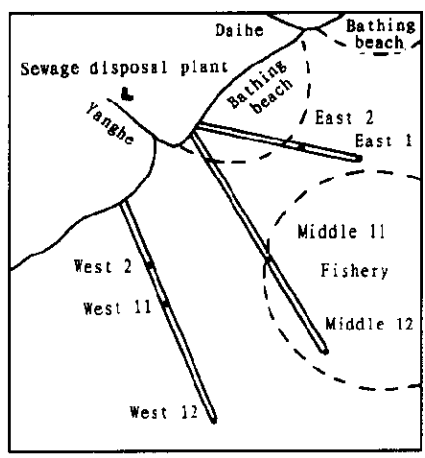

Fig. 5 Sewage draining pipeline and the preselected location of sewage draining outlet

4.2 Numerical simulation of COD in every preselected sewage draining outlet

Based on the numerical simulation of tidal current, mathematical model of pollutant dispersion and finite difference method were applied to forecast COD concentration in every sewage draining outlet. Dispersion equation and initial and boundary conditions are:

$$\frac{\partial(HP)}{\partial x}+\frac{\partial(HuP)}{\partial x}+\frac{\partial(HvP)}{\partial y}$$

$$-\frac{\partial}{\partial x}\left(HD_x\frac{\partial P}{\partial x}-\frac{\partial}{\partial y}\right)HD_y\frac{\partial P}{\partial y}=HS.$$

Where, u, v are the x, y components of velocity; P is the pollutant concentration; S is the draining speed of per unit volume pollution source; D_x, D_y are the dispersion coefficients in x, y direction, generally the following formulate is used.

$$(D_x, D_y) = 5.93Hg^{1/2}C^1(u, v),$$

boundary condition:

Land boundary : $\frac{\partial P}{\partial n}=0$, corresponding to tidal current velocity $Va=0$.

Open boundary: $P=0$ at rising tide,

$$\frac{\partial P}{\partial t}+Vn\frac{\partial p}{\partial n}=0 \text{ at ebb tide.}$$

Initial condition : $P=0$, $t=0$. Other conditions are as same as those used in the calculation of tidal current.

4.3 Calculation of sewage draining mixture area (expressed as COD_{Mn} factor) of every preselected sewage draining outlet

Space region which was not satisfied with the water quality standard required by function of sea are accepted sewage near sewage draining outlet existed, that was the exceeding standard area permitted in environment management, because too wide stipulation is unfavorable to environment protection of sea area accepted sewage and too strict stipulation could cause fairly high investment of sewage disposal engineering. Determination of allowable scope of mixture area involve many factors such as sea area function division, current situation, creature situation and sewage draining engineering condition and so on, some of which are difficult to describe quantitatively. Thus, there is not national standard in determination of allowable scope of mixture are now and should be determined according to specific engineering.

4.3.1 Recommended values of coastal sewage draining mixture area in Beidaihe(Table 1)

Table 1 Recommended values of coastal COD'_{Mn}s area of mixture area in Beidaihe

Limit of sewage draining outlet	Water depth, m	Mixture area , km^2
Sewage outlet must be	−5	0.25
built at the place out of	−7	0.50
1000m from bathing beach	−10	0.75
facing the sea	−15	1.00

4.3.2 COD_{Mn} sea draining amount of sewage disposal plant in Beidaihe Area(Table 2)

Table 2 COD_{Mn} sea draining amount of sewage disposal plant in Beidaihe Area (Unit: t/C)

Disposal degree	Planned year limit	
	Year 2000	Year 2010
Second-order disposal	1168	1752
First-order disposal	2219	3329
Predisposal	2920	4380

4.3.3 Calculation of mixture area of every preselected sewage draining outlet

There was fairly big difference in dynamic situation between water mass near sewage outlet and those relatively far from sewage outlet. So mixture area was divided into close area and distant area. Turbulent fluctuation effluxion theory was applied inclose area and mathematical model of pollutant dispersion described before(Section 4.2) was applied in distant area. At last the two areas

were coupled as a whole and the areas of mixture area in every preselected sewage outlet were calculated. They are shown in Table 3.

Table 3 COD'_{Mn}s areas of mixture area in every preselected sewage draining outlet

Number of sewage draining outlet	Length of sewage draining pipe, km	Water depth at sewage outlet, m	Area of mixture area, km^2		
			Second-order disposal	First-order disposal	Predisposal
East 2	1.9	−4.5	0.98		
West 2	1.5	−4.5	0.98		
East 1	3.1	−6		0.73	1.11
West 11	2.4	−6	0.55	0.73	1.11
Middle 11	2.7	−6		0.73	1.11
Middle 12	4.7	−7.5		0.50	0.67
West 12	4.7	−7.5		0.50	0.67

* Calculated according to the planned sewage draining amount of year 2010

4.3.4 Selection of sewage outlet location

Sewage draining pipeline I is nearer to Nandaihe bathing beach and national department bathing bach than II and III pipelines. It is unfavorable to the environment protection of the bathing beaches. Sewage draining pipeline II passes through the river mouth area and this does no good to safeguard of sewage draining pipeline because of the large change of scouring and deposit of sediment in the river mouth. More over sewage draining area locates within the fishery and it is not favorable to the environment protection of fishery. Thus, we recommend pipeline III to be the pipeline trend of this sewage sea draining works, east 11 to be the sewage outlet with two-order disposal whose pipeline length is 2.4 km and west 12 to be the sewage outlet with first-order disposal and predisposal whose pipeline length is 4.7 km.

4.4 Numerical simulation of sewage movement track

Movement track of sewage at sewage draining outlet were gained through out following the movement track of sewage particle at previous current field model of section 3 and applying mathematical model of two dimensional particle movement track. Sewage movement track of sewage draining outlet is shown in Fig. 6. It can be shown that selecting sewage draining pipeline III does much good to the protection of several important environment protection targets.

4.5 Exploration survey of transport and dispersion law of polluted sediment at sewage draining outlet

Besides polluted water, polluted particulate(suspension load and tractional load) also belongs pollutant drained into the sea from sewage disposal plant. The transferred destination of most of polluted material in water is still sediment because of its adsorption and sedimentation. So sediment pollution area is often formed neat sewage draining outlet which makes the ecological environment, especially the benthon be effected. Thus, not only the evaluation of polluted water influence, but also the evaluation of polluted sediment influence needs to be considered when carrying on the

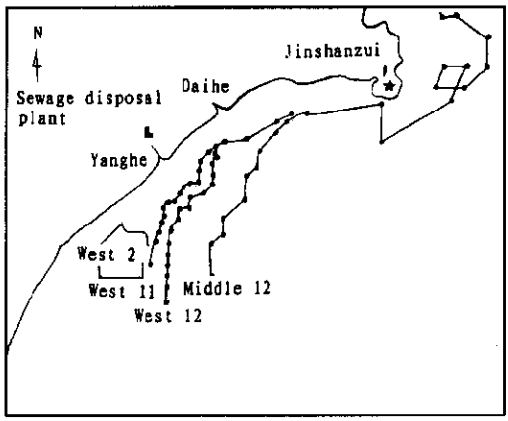

Fig. 6 Sewage movement track

result if transport of polluted sediment brings about seafloor of bathing beach to be polluted. We applied neutron tracer sediment technique to explore the transport and dispersion law of pollutant at sewage draining outlet. Transport and dispersion graph of polluted sediment is shown in Fig.7. Dotted line is the dispersion graph of polluted sediment at the third day after being thrown. It can be shown that main dispersion graph of polluted sediment at the second day after being thrown and real line is the dispersion direction of polluted sediment at sewage outlet is north-south direction and the direction with largest dispersion amount is south. O_1 is the center of gravity of polluted sediment aggregate at the second day and O_2 is the gravity center of polluted sediment aggregate at the third day. It can be seen from the changing trend of gravity center that movement direction of polluted sediment aggregate is south-west direction and this has no pollution influence on safflower of environment protection target in the study sea area.

research of sewage sea draining engineering. Only in this way can we gain comprehensive and scientific conclusion to pollution influence of sewage sea draining engineering. Evaluation of polluted sediment influence is not involved in many reports of environment influence evaluation of water environment realm for the limit of test methods. There are several important bathing beaches in the sea area accepted pollutant of the sewage sea draining engineering. Bathing beaches have relatively high requirement for quality of seafloor sediment(sediment) and it can cause serious

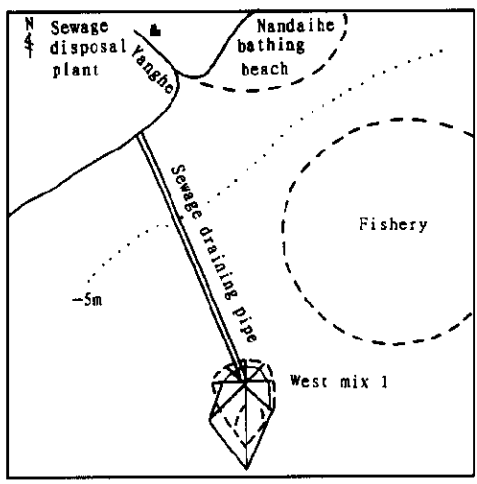

Fig. 7 Sketch map of movement law of polluted mud

5 Selection of sewage sea draining scheme at Beidaihe Area

Not only environment benefit but also engineering economic results should be considered in the determination of sewage sea draining scheme and selection and determination for scheme should be made on the basis of comprehensive analysis of the two aspects.

5.1 Comparison of environment benefit of every sewage sea draining scheme(Table 4)

Table 4 Comparison of environment benefit of every sea draining scheme

Sewage sea draining scheme	Water depth at sewage outlet, m	Length of sewage draining pipe	Mixture area, km^2	Influence on the target to be protected	Relative comparison of environment benefit
Draining into the sea at west 2 sewage outlet with second -order disposal	-4.5	1.5	0.98	Retain influence to coastal bathing beaches	Relatively bad
Draining into the sea at west 11 sewage outlet with second-order disposal	-6.0	2.4	0.55	No influence	Relatively good
Draining into the sea at west 12 sewage outlet with first-order disposal	-7.5	4.7	0.50	No influence	Good
Draining into the sea at west 12 sewage outlet with predisposal	-7.5	4.7	0.67	No influence	Relatively good

5.2 Comparison of engineering economic results of every construction scheme (Table 5)

Table 5 Comparison of engineering economic results of every construction scheme

Construction scheme of sewage disposal plant	Water depth at sewage outlet, m	Length of sewage draining pipe, m	Investment of sewage draining pipe(1×10^4 RMB Yuan)	Investment of disposal plant (1×10^4 RMB Yuan)	Total investment of engineering (1×10^4 RMB Yuan)	Total cost of motion (1×10^4 RMB Yuan)	Relative comparison of engineering economical results
Draining into the sea at west 2 sewage outlet with second-order disposal	-4.5	1.5	3360	12779	16139	2190	Relatively bad
Draining into the sea at west 11 sewage outlet with second-order	-6.0	2.4	5376	12779	18155	2190	Bad

Table 5 (Continued)

disposal							
Draining into the sea at west 12 sewage outlet with first-order disposal	−7.5	4.7	8675	4225	12900	1598	Relatively good
Draining into the sea at west 12 sewage outlet with predisposal	−7.5	4.7	8854	3032	11886	1417	Good

5.3 Selection of sewage sea draining scheme at Beidaihe Area

It can be made out from Table 4 and Table 5 that though environment benefit of draining into the sea at west 11 sewage outlet with second-order disposal is relatively good, total engineering investment and motion cost yearly are too high which must effect the start of the project or aggravate the burden of yearly motion costs of municipal works department. Environment benefit of predisposal and first order disposal and engineering investment and yearly motion cost have comparability, the difference is not large. Deepsea draining with first-order disposal is better than deepsea draining with predisposal in order to mitigate the entering amount of pollutant at polluted sea area. At last, we recommend deepsea draining (West 12 sewage outlet) construction scheme through the analysis and comparison of the above aspects. The construction scheme has been adopted by construction units.

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(Received February 16, 1997)