Distribution features of oil and preventive countermeasures in Meizhou Bay, China

Wang Xian, Chen Yu-wang, Li Weng-quan, Zheng Ai-rong

Department of Oceanography, Xiamen University, Xiamen 361005, China

Abstract—The content and distributive feature of oil in Meizhou Bay, China during summer were analysed on the basis of water quality survey. The result showed that oil concentration ranges between 5—51 $\mu g/dm^3$ with an average of 19.8 $\mu g/dm^3$. The mixed coefficient is lower. The difference of oil distribution between high tide and low tide is related to the distribution of land pollution and is mainly decided by water dynamics. Average turn-over rate and enrichment coefficient can provide fundamental information to estimate oil concentration in sea water.

Keywords: Meizhou Bay, oil pollution, mixed coefficient.

Meizhou Bay is in the middle of the western coast of Taiwan straits. The sea area is about 546 km^2. It is, with deep water and smooth sea, a natural good harbor which is surrounded by an important economic development zone in Fujian Province, China. Recent years, along with the opening and developing of coastal region, oil pollution in Meizhou Bay is becoming more and more serious. So, it is an urgent matter on how to evaluate, forecast and control the water quality. This essay is going to analyze the content and distributive features of oil on the basis of water quality survey (from June to August in 1992) and provide preventive countermeasures according to the special situation of water dynamics in this sea area. The purpose of the essay is to provide basic materials and scientific support for the rational used of Meizhou Bay.

1 Survey section

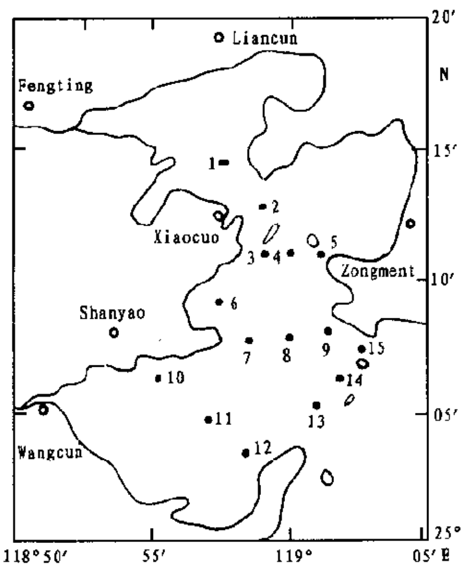

Fig.1 Distribution of survey stations

There are 15 survey stations in the target area from June to August in 1992(Fig.1).

The collecting of water samples on two voyages is carried out at both high tide and low tide. The surface sample is collected by oil collector, with depth of 1 m. The determination of oil content is done by ultraviolet spectrophotometer (according to principles on ocean survey, NMB, 1992) which is also suitable for that determination in the inshore and river mouth. After resting and improving the analysis method on lower oil concentration, the working curve showed that there are good positive correlations($r = 0.996$, $n = 6$) between 0—50 $\mu g/dm^3$. The instrument used is ultraviolet spectrophotometer (Model 752) with a tolerance of 1 $\mu g/dm^3$: those statistics come from 59 oil samples of the two voyages. Chlorophyll-a, extracted by acetone, is determined by spectrophotometer (Model 722; Wang, 1994).

2 Results and discussion

2.1 Horizontal distribution of oil in surface seawater

The results of the horizontal distribution of oil in surface water are shown in Fig. 2. It can be seen from Fig. 2 that during summer in Meizhou Bay, the oil in surface water ranges between 5—51 $\mu g/dm^3$ with an average of 19.8 $\mu g/dm^3$, at low tide, it ranges between 7—51 $\mu g/dm^3$ with an average of 19.2 $\mu g/dm^3$. At high tide, 5—44 $\mu g/dm^3$ with an average of 21.4 $\mu g/dm^3$.

The dilution and proliferation of water is mainly decided by water dynamics. Because Meizhou Bay is a harbor without big river's pouring in. Fig. 2 shows that, at high tide, horizontal distribution of oil in surface water is completely different from that at low tide. At low tide, the concentration gradient of oil showed a trend of increasing progressively from top of the bay to the low. While at high tide, decreasing progressively. Those features showed that the dilution and proliferation of water in Meizhou Bay are closely connected with the water dynamics such as tide and wave. After flowing into the sea, the water-soluble part of oil enters into the seawater and the other parts float and volatilize with wind and surface current. Besides, the tide range is high and the containing ability for tide is also high. Exchange of seawater is done by mixing of tides. The exchange ability of seawater, when near the entrance of the bay, is the strongest with best environmental capacity; in the bay, is weaker and on top of the bay, is the weakest with least capacity.

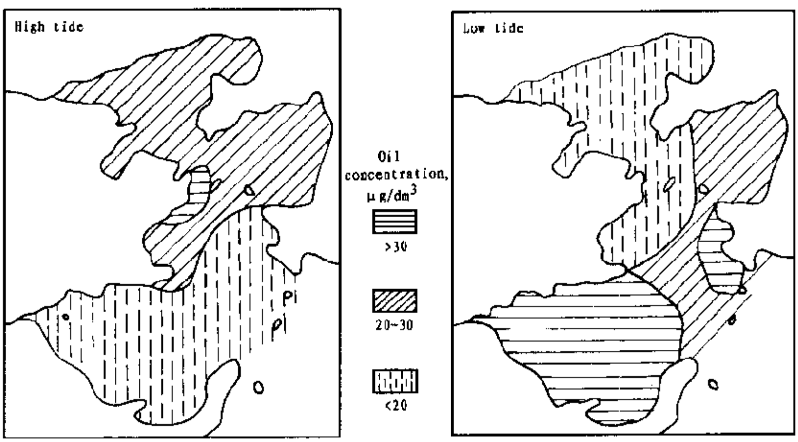

Fig. 2 Horizontal distribution of oil in surface water

2.2 Major cause of pollution and distribution features of oil

Fig. 3 shows the distribution of major pollution stations and maximum oil content in surface water during the survey. No.9, 14 and 15 are near ship-separating factory. No.3 is at the oil wharf while No.11 and 12 are under the sewage line. Obviously, maximum oil content in surface water is connected with not only the tide range but also the pollution stations. Although during the survey, oil content in surface water of Meizhou Bay does not exceed water quality standard(50 $\mu g/dm^3$) of national fishery (only one station exceed 6%), the high oil content near pollution stations should be paid enough attention. This result is the same with the other reports(Cai, 1993).

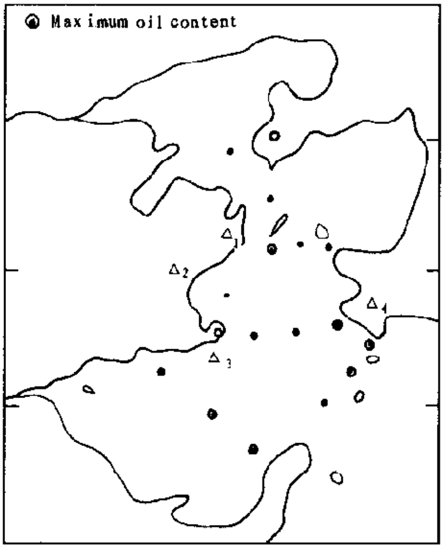

Fig. 3 Distribution of pollution stations

2.3 The relationship between average turn-over rate of seawater and accumulation quantity of oil

Meizhou Bay is with little runoff from land. The dilution, proliferation and selfpurification ability of its water are closely related with average turn-over rate of seawater. It belongs to former half-day tide. The mixing, diluting, exchanging and moving of oil is chiefly decided by containing ability for tide. The literature(Pan, 1992) took Meizhou Bay as a single-box model. Suppose seawater in the bay exchanges directly with that out of the bay and even mixing, according to conservation of mass, the average turn-over rate of seawater is 0.127. In pace with development of industry around the bay, the content of oil will increase while the exchanging, diluting and proliferating of water will reduce the pollution. Thus, the relationship between oil quantity increasing as time prolongs and that decreasing when changed with seawater can be stated according to following statistic theory and some related materials(Dong, 1993).

Suppose average turn-over rate of seawater is μ, and the quantity of oil accumulation before the first exchange is $C(\mu g/dm^3)$, then the quantity of oil accumulation after the first exchange should be $C - C_\mu = C(1-\mu)$; before the second, $C + C(1-\mu)$, after second, $[C + C(1-\mu)](1-\mu) = C(1-\mu) + C(1-\mu)^2$, the rest may be deduced by analogy, before the Nth, $C + C(1-\mu) + C(1-\mu)^2 + C(1-\mu)^3 + \cdots\cdots + C(1-\mu)^n$. Thus the common ratio is $(1 \quad \mu)$. According to geometrical progression formula, the sum before the Nth is

$$Cs = C[1-(1-\mu)^n]/\mu. \tag{1}$$

Where, Cs is the average oil contents($\mu g/dm^3$) after the Nth exchange, N could be calculated by month or year.

According to the result of survey, the average month content of oil in Meizhou Bay is 0.91 $\mu g/dm^3$, the average accumulation of a year is 10.8 $\mu g/dm^3$. Suppose μ is 0.127, put this result into Formula(1), the average oil content in Meizhou Bay could be 20.2 $\mu g/dm^3$ in 1993 and 21.3 $\mu g/dm^3$ in 1994. Comparing with relevant statistics (21.3 $\mu g/dm^3$ in 1993 and 26.1 $\mu g/dm^3$ in 1994), relative deviations are 5% and 22.5%. This result showed that Formula(1) could predict the changing trend of the average oil content in Meizhou Bay. From the calculation of Formula(1) it can be known by the end of this century, the oil content in Meizhou Bay would reach 50 $\mu g/dm^3$, which is the limit of the first seawater quality standard. Along with the development of the economic development area near Meizhou Bay, the oil content in seawater could reach higher than what is predicted. So, it should be paid enough attention by relative department.

2.4 Mixing and moving of oil

If one once entering sea, oil will mix with seawater under the effect of wave and tide. The document (Dong, 1993) put forward the mixing formula of water salinity in the thin salt mixing area of the river mouth according to the conservativity of salinity in the seawater:

$$n = |S_b - S_s|/S, \tag{2}$$

where, S_b is the bottom salinity number; S_s is the surface salinity number, S is the average number of the bottom salinity; n is the mixing coefficient. The less n means the better surface and bottom are mixed. Document(Ke, 1989) holds that this could be an indicator of mixing degree between surface and bottom oil in the sea area and oil moving from surface to bottom. Mixing coefficients in seawater when at low or high tide in some stations are got from Formula (2) and seawater salinity calculation in Meizhou Bay during the survey (Table 1). The result showed that whenever at low or high tide, the changing trend of n is consistent. That is, n changes from large to small when from top to the outside of the bay. The number of n in the inside and outside of the bay is small. It showed well-mixing of the surface and the bottom, consistent of half-mixing of the surface and the bottom, consistent to half-changing period of seawater discussed in document(Pan, 1992). Besides, because Meizhou Bay has no big river's input and is not a mixing area of river mouth and seawater, during the survey, the salinity changing range of the surface and the bottom sea is not large(30.73—32.99), so the mixing coefficients are small. Mixing procedure is decided by the advance and return movement of tide (the direct exchange between inside and outside seawater). All these prove that mixing and moving of oil in Meizhou Bay are controlled by water dynamic conditions.

Table 1 Mixing coefficients in Meizhou Bay seawater

Stations		1	4	8	13
n, mixing	Low tide	2.7×10^{-3}	2.9×10^{-3}	1.9×10^{-4}	1.3×10^{-4}
coefficients	High tide	1.0×10^{-3}	1.8×10^{-3}	4.5×10^{-4}	3.1×10^{-4}

2.5 Relationship between oil content and chlorophyll-a

Seawater surface (photic zone) is beneficial for the growing of phytoplankton and has strong accumulating effect on oil component. Thus it is also beneficial for the elimination of oil component in seawater(Zang, 1991). During the survey, on the surface water of Meizhou Bay, the content of chlorophyll-a (Chl.-a) is 0.45—4.72 mg/m^3, average value is 1.49 mg/m^3 (Wang, 1994). Making Chl.-a and oil content (C) linear return, the content of Chl.-a is in a better interrelated relationship with C, on the surface of Meizhou Bay Chl.-a $= 0.08372C - 0.03145$ ($r = 0.5783$, $n = 31$). It means, if oil is not beyond standard, dissolved oil component has stimulating effect on marine phytoplankton. As study(Barden, 1991) showed oil component may either stimulate or inhibit the cell division speed of algae and photosynthesis and assimilation effect of carbon. Under the circumstance of lower concentration of dissolved oil component (0.01—0.5 mg/m^3), it is not surprising that carbon assimilation speed of algae has been raised. For oil has multiple component, both biotoxin and biological activity component while the later has been proved to have stimulating effect on marine phytoplankton. The result of the writer's survey holds the same view with it, but the effective elements on the primary productivity of seawater are very complicated, closely related with environment factor. If we only consider the effect of oil contents, when we raising density of oil or extending the contact time, stimulating effect would change to inhibiting effect.

3 Preventive countermeasures

The distribution of oil content in Meizhou Bay are not only related with the distribution of land pollution source, but also mainly decided by water dynamic conditions of this area.

The mixing coefficient of seawater in Meizhou Bay is small. It showed that the mixing and moving of oil in seawater are mainly controlled by water dynamic conditions.

The natural species of phytoplankton in Meizhou Bay have certain effect on the diluting and removing of oil.

Average turn-over rate of seawater and average accumulating quantity of oil yearly could be the basis to predict the changing trend of oil density in Meizhou Bay.

In order to protect and supervise the marine environment of Meizhou Bay, to develop the economic development zone along the bay, the following countermeasures should be adopted according to the above conclusion: (1) Strengthen the control of marine pollution and stick to the law of marine environment protection of PRC. That is the premise to quarantee the marine environmental quality of Meizhou Bay; (2) monitor and analyse the condition of oil pollution of this area regularly, especially the forecast on changing quantity yearly and changing trend; (3) emission of major pollution source should be carried strictly according to the regulation for rubbish dumping at sea. While the emission should be done on the ebb. The outlet had better be installed near the outside of the bay after a thorough investigation; (4) to raise primary productivity of this sea area is an effective method to low the oil content of seawater.

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