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A Study on the Characteristics of the Circulation and Diffusion in Suyeong Bay

Young-seup KIM*, Young-ho HAN**

Simultaneous investigations for drift bottle and dye diffusion experiment were carried out in Suyeong bay.

Seawater in Suyeong bay flowed differently in the vicinity of Suyeong river estuary and Namcheon Dong respectively. The speed of current did not exceed one knot in this bay.

The dye patch moved to Kwangan beach in the dye diffusion experiment.

Th e relationship between apparent diffusivity and diffusion time was appeared as $Ka=0.0025t^{1.9}$. The variance was calculated to be 2.9 power of the diffusion time.

And the exponent of apparent diffusivity versus the scale of diffusion time was appeared to be 1.3.

Introduction

For the most purposes, many investigators have carried out the circulation experiments by means of using current meter, drift current drogs, drift bottles as well as dye materials. Of course, the main purpose of the dye diffusion experments is to know the characteristics of the pollutant diffusion, but it can be also easily obtained the direction or speed of seawater in a certain area through such experiments. The dye diffusion experiment, therefore, is an available method in studying the circulation in a coastal area.

Meanwhile, the processes of the oceanic diffusion are so quite complex that can hardly explain or interpret the entire pattern of diffusion.

Under the some ideal conditions, thus the studies on diffusion were developed by Taylor (1921), Frenkiel (1953), Townsend and Batchelor (1956) and many others.

But, laboratory or theoretical data appear to be entirely nonexistant. In natural bodies of water, thus using fluorescent tracer dyes, instantaneous concentration measurements in a diffusing patch or plume are relatively easily carried out.

It have been made through the in *situ* experiments to study diffusion in a certain area (Inoue, 1950, 1951; Olson and Ichye, 1959, 1960; Okubo, 1962, 1971).

In coastal area of Korea, dye diffusion and circulation experiments were carried out by Chang (1969, 1977), Han and Yoon (1970), Ro (1980) Lee and Chung (1981), Han *et al* (1982) and many others.

Suyeong bay in the vicinity of Busan harbor or estuary of Suyeong river is connected with two big beach resorts, and surrounded by residential district and many factories. This bay, therefore, recieves much water and sewage, and are considered as seriously contaminated bay in Korea.

The purpose of this paper is to investigate the

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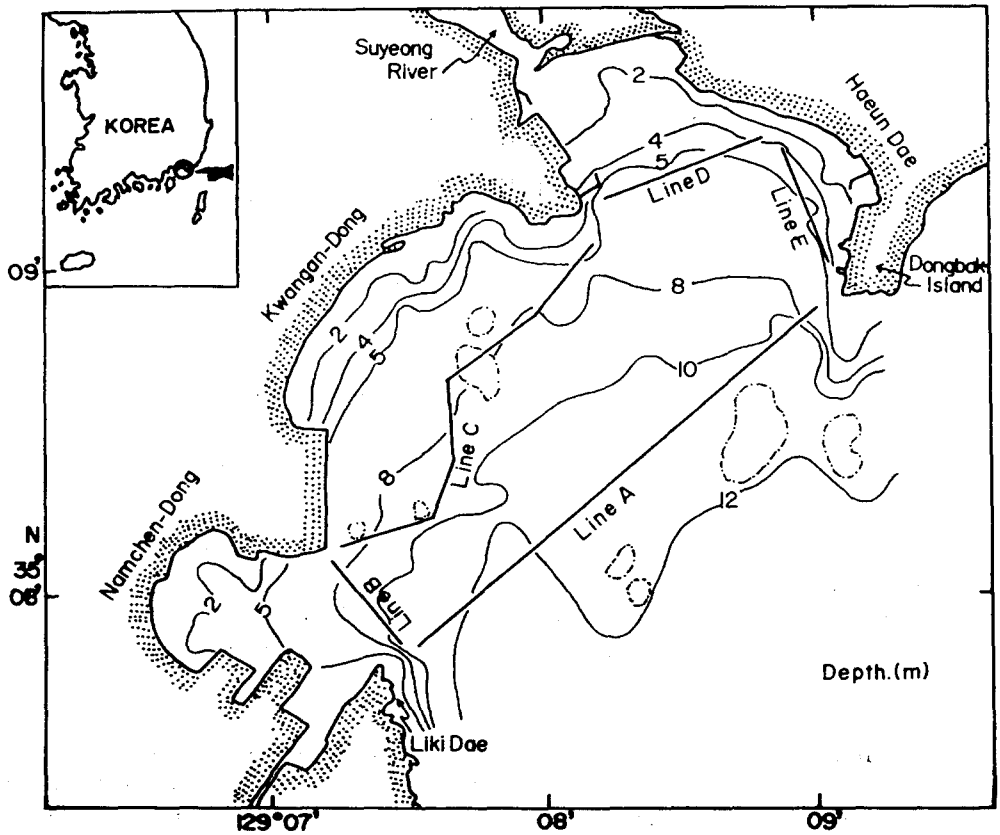

Fig. 1. Line of drift bottle release and bottom topography in Suyeong bay.

characteristics of the circulation and diffusion in Suyeong bay through the drift bottles experiment on June 26, 27, October 17, 1976, and dye diffusion experiment on september 4, 1982.

Material and Methods

A. Drift bottles experiment

These experiments were made along the releasing line as shown in Fig. 1. at flood (1 time) and ebb tide (3 times) respectively. Ballasted with 90g sand, glass drift bottles of 350cc in volume were prepared to reduce the direct influence of wind. Drift bottles were tracked on small boat. The positions of the drift bottles and tracking boat were determined by using sextant and magnetic compass.

B. Dye diffusion experiment

Rhodamine B was used as a dye in this experiment. Mixed with methanol, Rhodamine in solution was prepared to match density with in *situ* sea water.

The dye solution was carefully released at the surface of point A (Fig. 4.) by using the instantaneous releasing method during the ebb of spring tide.

Dye patches were tracked on small boat, and dyed water was sampled with the D. C. pump (3v).

Spatial and temporal sampling intervals and the numbers of sampling intervals and the numbers of sampling point are shown in Table 1.

Spectrofluorometer was used to meaure the concentrotion of sampled water.

Variance and apparent diffusivity of dye patc-

Table 1. Dye diffusion experiment data in Suyeong bay.

Tide	Release time	Diffusion time(min)	Sampled interval(m) X-axis	Y-axis	No. of Sampling stations X-axis	Y-axis
Ebb	10:35	30	10	10	10	5
		60	30	10	13	6
		90	50	15	11	6

hes was computed by using the standard statistical method (Murthy, 1970) and Okubo's empirical formula (1971) respectively. And also we calculated the scale of diffusion as $3\sigma_{rc}$.

Results and Discussions

A. Drift bottles experiment

A number of 630 bottles were released, and mean recovery rate was about 20%.

Fig. 2. and Fig. 3. are drawn from the results of the drift bottle experiment at the flood and ebb tide respectively.

As shown in Fig. 2., at flood tide, water coming to Suyeong bay from off sea flows to western side of Dong bak island, and water coming from the northeastern side of Liki Dae runs to the coast in front of Dong kuk steel co..

Apparently flood current flows fast (about 1 knot) at the southwest side of Dong bak island compar to the speed of about 0.3 knot in the vicinity of Liki Dae.

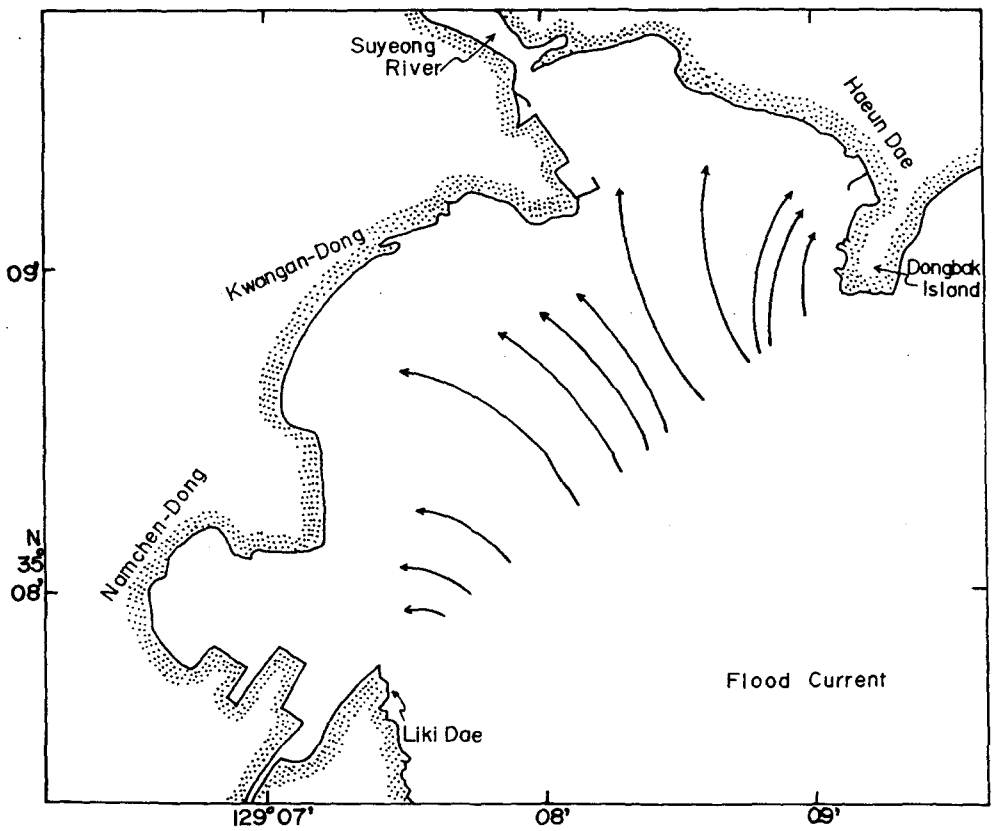

Fig. 2. Drift bottle experiment data, flood current.

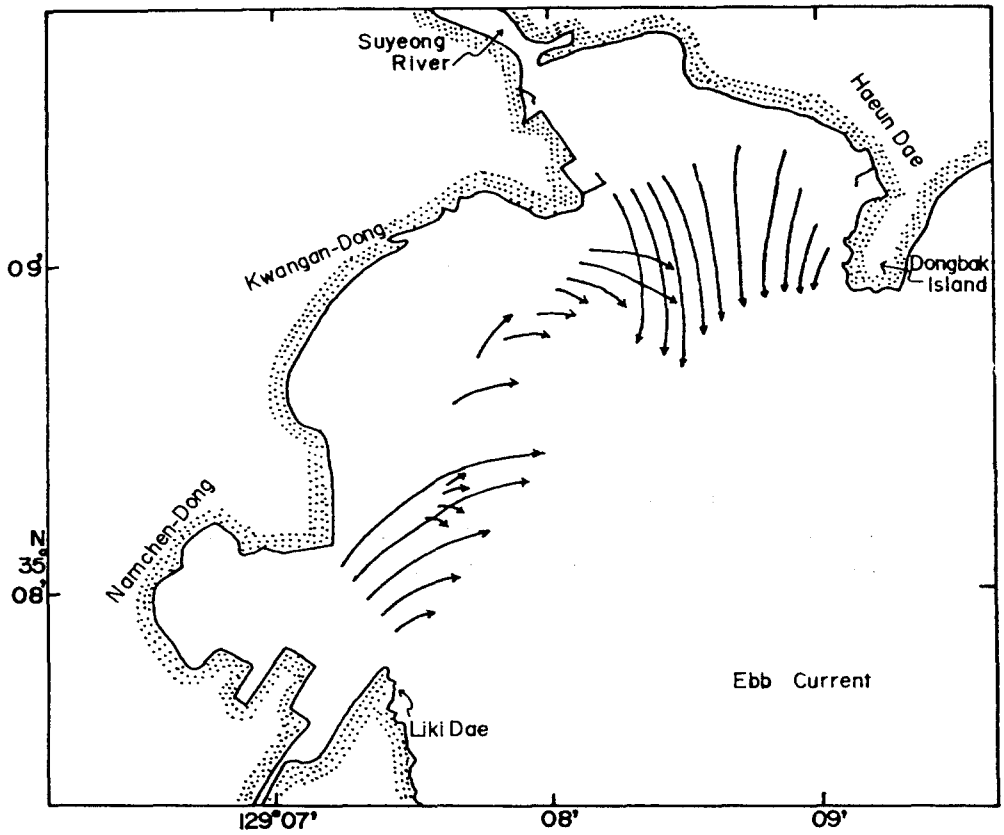

Fig. 3. Drift bottle experiment data, ebb current.

As shown in Fig. 3., seawater coming from Suyeong river estuaryand western side of Dong bak island flows out sea through the center of bay, and water runs northeastward and then turns smoothly to the right in front of Namcheon Dong and Dong kuk steel co.. Ebb current flows fast (about 1 knot) in the vicinity of the center of bay and Namcheon Dong, and slow (about 0.2 knot) in front of Kwangan Dong.

B. Dye diffusion experiment

Diffusion experiment was carried out at the ebb of spring tide on September 4, 1982.

During the investigation, ebb current flowed southeastward with speed of about 0.8 knot, and the sea state was very rough with strong wind (direction: NW, speed: 7-8m/sec) and high wave (about 1.5m) with white caps.

The dye patch moves westward to Kwangan beach as shown in Fig. 4. Although the strong

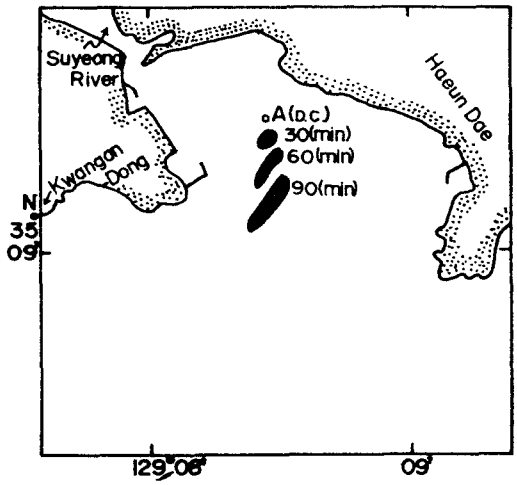

Fig. 4. Dye discharge point and patch diagram of ebb flow.

Table 2. Results of the dye diffusion experiment in Suyeong bay.

Release time	Diffusion time(*min*)	Variance(m^2) σ_x	σ_y	σ_{rc}^2	Ka (cm^2/sec)	L (*cm*)
10:35	30	17	9	306	425	5248
	60	84	15	2520	1750	15060
	90	120	35	8400	3889	27495

wind was blowing southwestward, it suggests that the sericusly contaminated water which comes from Suyeong river can pollute in vicinity of Kwangan beach.

Table 2. shows the results of diffusion experiment in Suyeong bay.

The relationship between apparent diffusivity and diffusion time are computed as $Ka=0.0025t^{1.9}$ from the Table 2.

Apparent diffusivity at diffusion time 60 minutes is about $2.5\times10^3 cm^2/sec$.

This value is smaller than the result of $7\text{-}8\times10^3 cm^2/sec$ at Kori(Ro, 1980), and larger than that of $1.2\times10^3 cm^2/sec$ in Jinhae bay (Han *et al*, 1982).

If we consider that the sea state was relatively rough during the experiment, we appreciate that diffusing power is very weak in this bay.

By plotting the value of the variance, σ_{rc}^2, against diffusion time, t, Fig.5. is drawn. The variance of the dye patch is computed to be 2.9 power of the diffusion time.

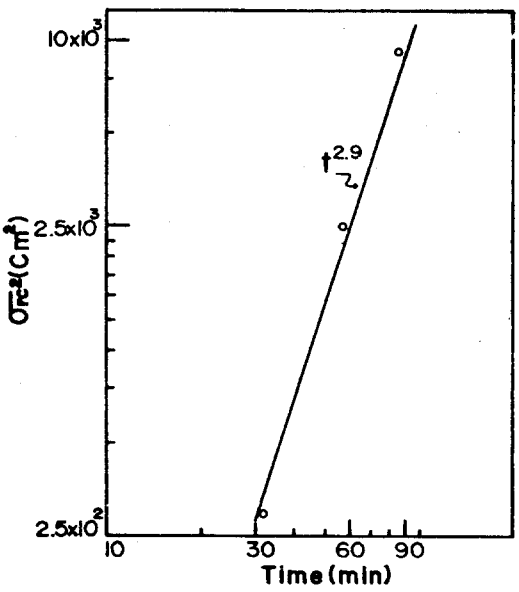

Fig.5. Variance versus diffusion time.

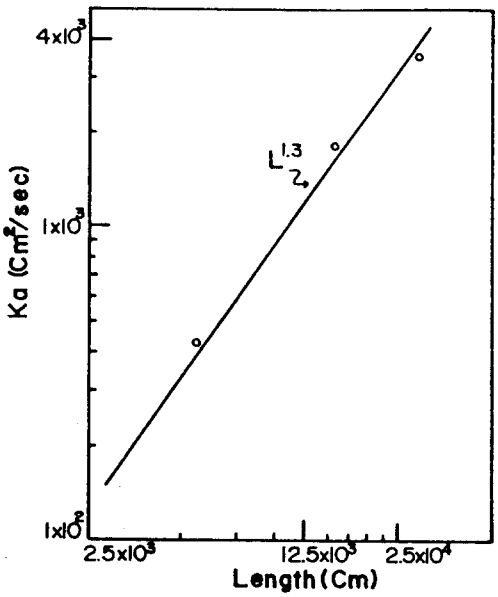

Fig.6. Apparent diffusivity versus scale of diffusion.

Okubo (1971) described that the variance increase with time at a power between 2 and 3 in natural bodies of water. The exponent of 2.9 in this experiment shows the intermediate values between 2 and 3.

Fig.6. shows the relationship between the apparent diffusivity, Ka, and a scale of diffusion, 1.

Many investigators have proposed the 4/3 law of oceanic diffusion (Stommel, 1964; Ichiye and Olson, 1960).

Recently the 4/3 power law of oceanic diffusion is considered as a standard assessment barometer.

The exponent of 1.3 given in Fig.6. satisfies

the 4/3 power law.

Conclusion

Simultaneous investigations for drift bottles and dye diffusion experiment were carried out in Suyeong bay.

At the flood tide, water coming to Suyeong bay from off sea flows to western side of Dong bak island, and water coming from the northeast of Liki Dae streams to the coast in front of Dong kuk steel co..

At the ebb tide, seawater coming from Suyeong river estuary and western side of Dong bak island flows out off sea through the center of bay, and water runs northeastward and turns to the right in front of Namcheon Dong and Dong kuk steel co..

The speed of current in this bay dosen't exceed one knot. The dye patch moves to Kwangan beach in the dye experiment.

The relationship between apparent diffusivity and diffusion time is appeared to be $Ka = 0.0025t^{1.9}$.

The exponent of variance versus diffusion time and apparent diffusivity against the scale of diffusion are appeared as 2.9 and 1.3 respectively.

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A Study on the Characteristics of the Circulation and Diffusion in Suyeong Bay

水營灣의 海水流動과 擴散特性에 關한 硏究

金 榮 燮* · 韓 英 鎬**

漂流瓶 및 染料擴散實驗을 通하여 水營灣의 海水流動과 擴散特性을 査調하였다.

밀물때 海水는 冬柏섬 南西端에서 時計方向으로 돌아서 冬柏섬 西端으로 흐르고, 이기대 北東端 附近에서는 反時計方向으로 돌아서 東國製鋼 앞쪽으로 흘렀다. 이때 流速은 冬柏섬쪽에서 約 1놋트 程度였고 이기대 附近에서 約 0.3놋트였다.

썰물때 海水는 水營江 河口와 冬柏섬 南西쪽으로부터 灣의 中央附近을 거쳐 灣外로 흘러나가고 南川洞과 東國製鋼 앞쪽에서는 時計方向으로 돌아서 水營江 河口에서 흘러나오는 海水와 合流하여 灣바깥으로 흘러나갔다. 流速은 灣의 中央과 南川洞앞쪽으로 약 1놋트 정도로 빨랐고 廣岸海水浴場앞에서 約 0.2놋트 程度로 느렸다.

染料의 擴散域은 廣岸海水浴場쪽으로 移動하였으며 90分後겉보기 擴散係數는 3.9×10^3 cm²/sec 程度였다. 이값은 鎭海의 1.2×10^3 cm²/sec 보다는 큰 값이지만 고리해역의 $7\text{-}8\times10^3$ cm²/sec에 比하여 1/2에 불과하다.

擴散時間에 對한 分散指數는 2.9, 擴散規模에 對한 겉보기 擴散係數는 1.3으로 나타났다.