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# The Diffusion Coefficient of Seawater in Ao Si Racha

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## ABSTRACT

The diffusion coefficient of seawater was calculated by using the statistical procedure of periodicity of the tidal current data. When the autocorrelation coefficient became insignificantly different from zero after some time lag, the estimate of diffusion coefficient of seawater was straightforward. The observed velocities of seawater every 10 minutes had been carried out by using SD 6000 current meter 2 meters below sea surface at Ao Si Racha for 20 days (100°55′00″E, 13°11′08″N or 707750E, 1458474N) in October 2004, May 2005 and September 2005. The order magnitude of the diffusion coefficient of seawater in East-West and North-South direction at Ao Si Racha were in the range of 0.3-1.8 $m^2$/sec. The diffusion coefficient of seawater along the North-South direction was higher than in the East-West direction which agreed well with the stronger tidal current condition in the North-South direction.

## INTRODUCTION

Ao Si Racha, Chon-Buri Province is a small semi-open bay. It is situated at the eastern part of the upper of Thailand. The type of the coast here are mud flat, sandy beach and rocky shore. The northern part is Laem Samuk and the southern part of Ao Si Racha is Laem Chabang industrial estate. The site covers 680000-710000 E and 1440000-1470000 N about 900 $km^2$ as shown in Figure 1. The averaged gulf depth is approximately 15 to 20 meters and the maximum depth is approximately 29 meters in the southern part. In this area the type of the tide is mixed principally diurnal tide. The movement of seawater is mainly driven by tide. The maximal magnitude of tidal current is about 0.8 m/s. The directions of the flow are northward during flood tide and southward during ebb tide which are parallel to the coast.

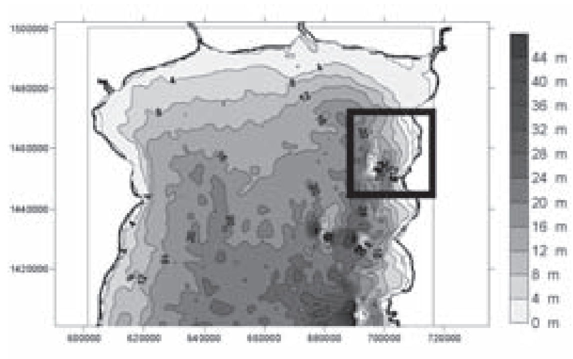


**Figure 1** Plot of the adjusted bathymetry.

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## MATERIALS AND METHODS

The observed velocities of seawater every 10 minutes had been carried out by using SD 6000 current meter at 2 meters below seawater surface at Ao Si Racha for 20 days (707750E, 1458474N) in October 2004, May 2005 and September 2005. The moored current meter was shown in Figure 2.

Taylor's (1921) hypothesis for expressing diffusivity in terms of Lagrangian statistics was used in this study. Taylor showed that the diffusion coefficient, ε ($cm^2$/sec.) of substances could be expressed as a product of mean square of the fluctuation velocity, $\nu'$ and Lagrangian integral time scale of large diffusion time.

$$\varepsilon = \overline{\nu'^2} \int_0^\infty R_L(\tau)d\tau \qquad (1)$$

where $\tau$ = dummy lag time variable

$R_L(\tau)$ = Lagrangian correlation coefficient

$\int_0^\infty R_L(\tau)d\tau$ = Lagrangian integral time scale

Since Lagrangian intergral time scale in case of fluid was very complicated to determine. In this study, Eulerian integral time scale was used to estimate the eddy diffusion coefficient by Hay and Pasquill(1959), which could be expressed as:

$$\varepsilon = \overline{u'^2} \beta \int_0^\infty R_E(\tau)d\tau \qquad (2)$$

where $\overline{u'^2}$ = intensity of turbulence in x component

$R_E(\tau)$ = Eulerian correlation coefficient

$\int_0^\infty R_E(\tau)d\tau$ = Eulerian integral time scale

$\beta$ = ratio of Lagrangian to Eulerian integral time scale.

Sasaki and Inoue (1984)' s observations expressed as:

$$\beta \cong 0.8\left(\frac{U_E}{\sqrt{\overline{u'^2}}}\right) \qquad (3)$$

where $U_E$ = moving average of velocity every 1 hour

Narasimhan (1996) estimated= 1.0, then the eddy diffusion coefficients could be shown as:

$$\varepsilon = \overline{u'^2} \beta \int_0^\infty R_E(\tau)d\tau \qquad (4)$$

## RESULTS AND DISCUSSION

The observed velocities of seawater had been carried out by using SD 6000 current meter deployed at Ao Si Racha in October 2004, May 2005 and September 2005. In this area, there are 2 tide cycles per day. The period for one cycle is about 12 hours 25 minutes. During flood tide, seawater is northward flow. And during ebb tide, seawater is southward flow.

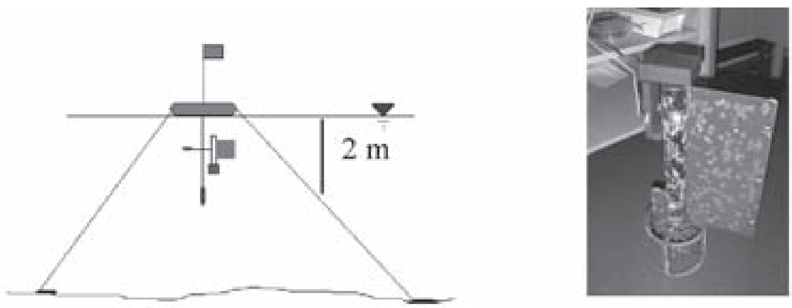


**Figure 2** The diagram of the moored current meter.

**Table 1** Computed diffusion coefficient of seawater in North-South and East-West direction in Ao Si Racha ( $\beta \cong (\frac{U_E}{\sqrt{u'^2}})$).

| Period | $U_E$, (cm/sec) | $\sqrt{u'^2}$ , (cm/sec) | $\int_0^\infty R_E(\tau)d\tau$ , (sec) | e, ($cm^2$/sec) |
|---|---|---|---|---|
| October-04-NS | 18.8 | 65.1 | 9.3 | 11320 |
| May-05-NS | 20.5 | 66.5 | 9.1 | 12449 |
| August-05-NS | 23.6 | 68.5 | 11.0 | 17778 |
| October-04-EW | 12.1 | 35.3 | 8.6 | 3664 |
| May-05-EW | 13.7 | 35.9 | 7.9 | 3867 |
| August-05-EW | 17.1 | 41.6 | 7.3 | 5216 |

The order magnitude of the diffusion coefficient of flow in East-West direction and North-South direction at Ao Si Racha was found to be in range of 0.3-1.8 $m^2$/sec as shown in Table 1. However, the value of diffusion coefficient of seawater in the North-South direction was observed to be slightly higher than in the East-West direction. Hence, a better mixing could be expected in the North-South direction.

Narasimhan (1996) reported that the order of magnitude of the diffusion coefficient of seawater in East-West and North-South direction at Sichang and Hua Hin was in the range of 1-5 $m^2$/sec. The values of diffusion coefficient of seawater in the North-South direction were observed to be slightly higher than in the East-West direction. Hence, a better mixing also could be expected in the North-South direction.

Boonchum (2005) studied the horizontal diffusion coefficient of seawater which indicated how fast the dissolved or suspended substances disperse in the water. He found that the mean diffusion coefficient of seawater computed from the experiments was 2.09 $m^2$/sec and the mean dispersion coefficient was 0.32 $m^2$/sec.

There were essentially two distinct ways in which mixing and suspended with seawater were brought by natural turbulence in the sea. When outfall was discharged from one of many rivers of diffuser, it had kinetic energy due to its velocity, and potential energy due to its submergence. This energy was dissipated in the turbulent mixing with the surrounding seawater. Analysis of this phenomenal had been presented by Rawn *et al*.(1960)

Orlob(1958) and Pearson (1956) had given a summary of diffusion laws as related to the ocean disposal as shown in Figure 3. One thing was clear, the magnitude of the diffusion coefficient increases greatly with the size of the area or volume being considered. A stream of pollutant was mixed with the seawater by irregular motions or turbulence of the seawater. Turbulent fluctuations tending to disperse the stream were

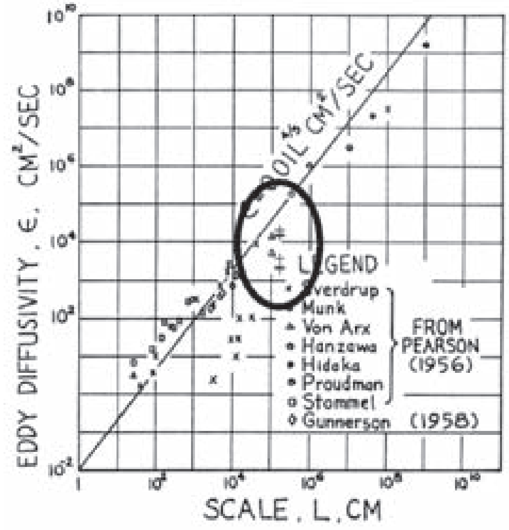


**Figure 3** Measured values of eddy diffusivity in the horizontal direction in the ocean, showing increasing with scale.

superimposed on some mean motion. It would promote mixing only if the stream being dispersed was larger than the characteristic parcel or eddy size. Thus intuitively there were some grounds for believing that it was reasonable to have a diffusion coefficient which increased with the scale of that which was being mixed.

Stommel (1949) showed how the similar “4/3-law” for eddy viscosity might be deduced theoretically on the basis of the Weizsacher-Heisenberg or Kolmogoroff theories. It was assumed here that the diffusion of mass and momentum were essentially similar that the order of magnitude of the eddy viscosity and eddy diffusivity were the same. The coefficient for vertical diffusion was usually several orders of magnitude less than the horizontal diffusion because of the stability caused by density stratification in the ocean (Munk, et all, 1949).

According to the above mentioned, the results of computed eddy diffusion coefficient of seawater in Ao Si Racha were reliable since the range of the values e which were related to L in the order of $10^4$-$10^6$ cm were $10^3$-$10^5$ $cm^2$/sec, respectively. The autocorrelation coefficient curves of velocity in East-West direction and North-South direction were similar pattern. They had strongly agreed relation every 12 hours 30 minutes as shown in Figure 4. The magnitudes of coefficients in North-South direction were larger than in East-West direction.

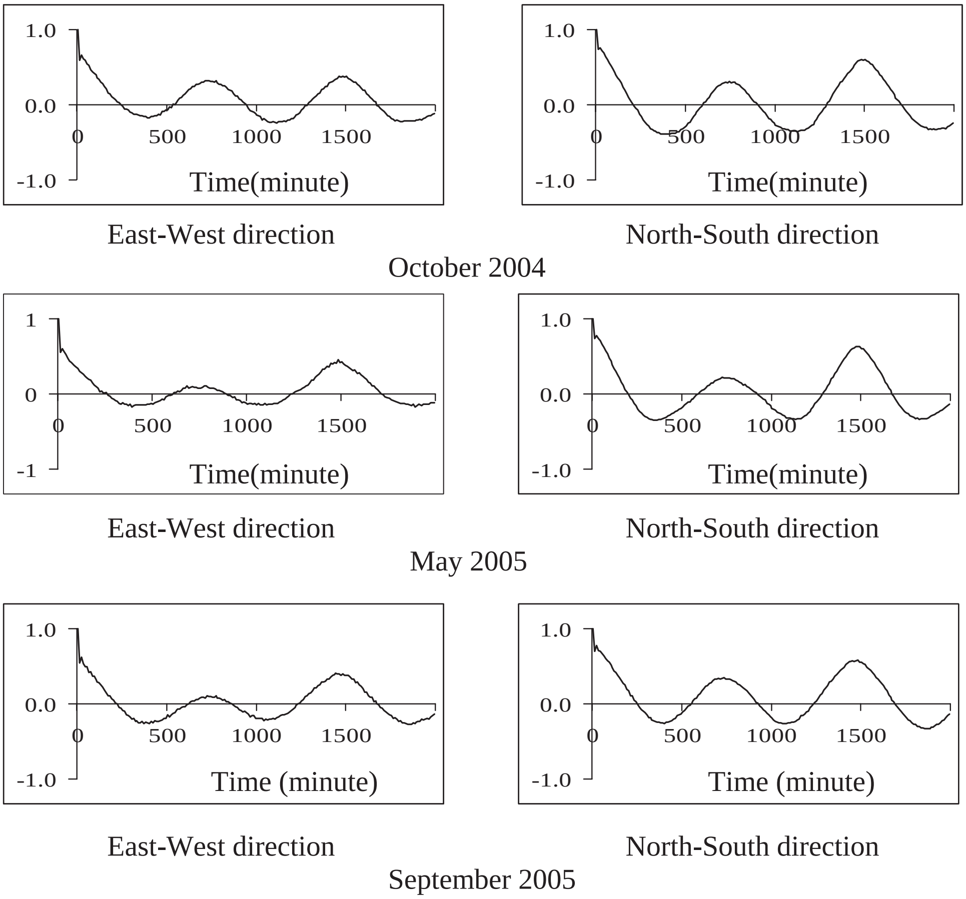


**Figure 4** Autocorrelation coefficient curves of velocity in the East-West and North-South direction at Si Racha fisheries research station in October 2004, May 2005 and September 2005.

## CONCLUSION

The study of diffusion coefficient of seawater was undertaken in Ao Si Racha using a statistical method. Based on the similarity of the auto-correlations of the micro-scale Eulerian and Lagrangian velocities, the coefficient was expressed as the product of the Eulerian time scale and the mean of the Eulerian velocity fluctuations squared. The diffusion coefficient of seawater in the North-South direction was found to be higher in magnitude than in the East-West direction which was a result of stronger current prevailing in the North-South direction.

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