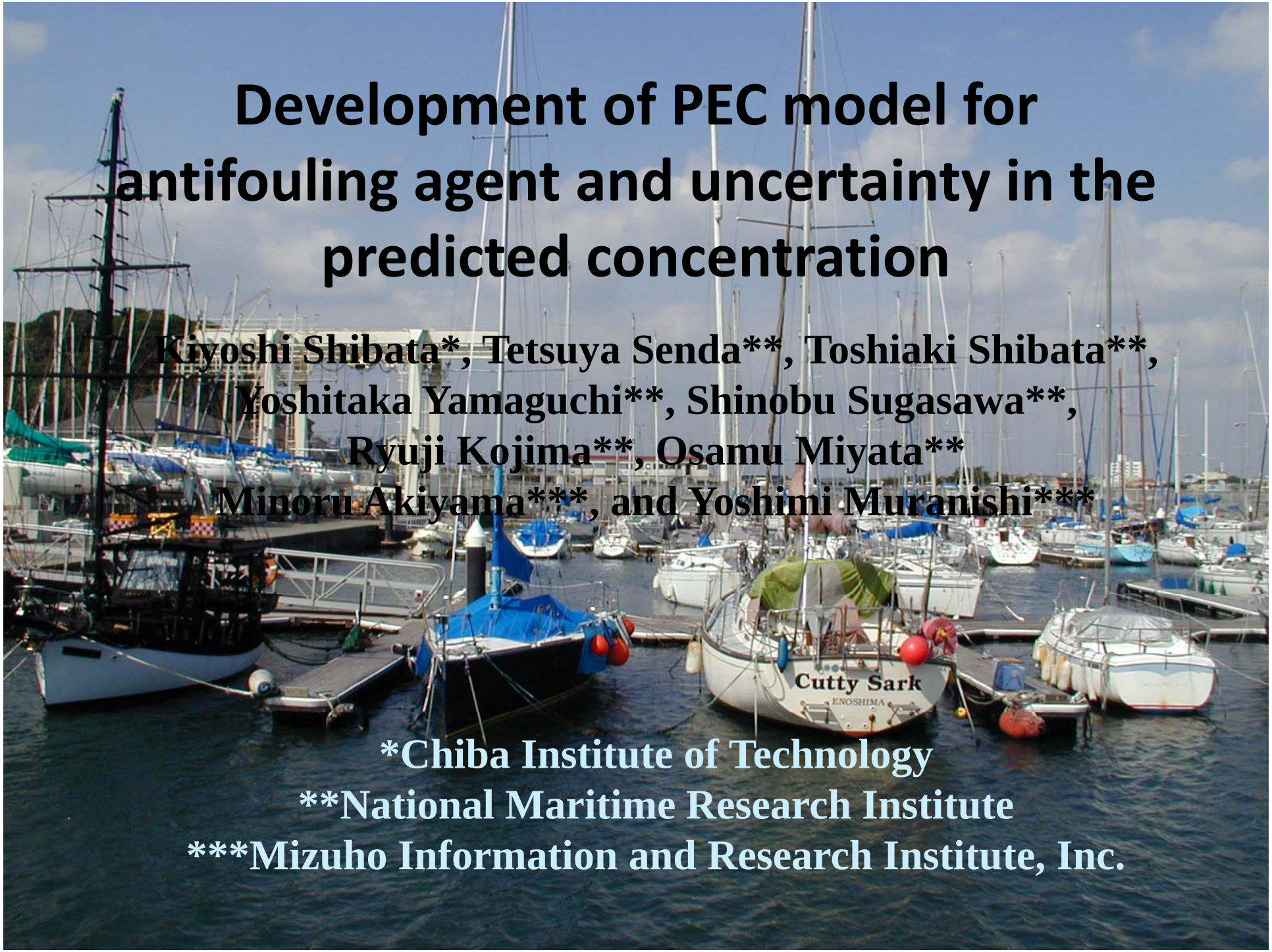

Development of PEC model for antifouling agent and uncertainty in the predicted concentration

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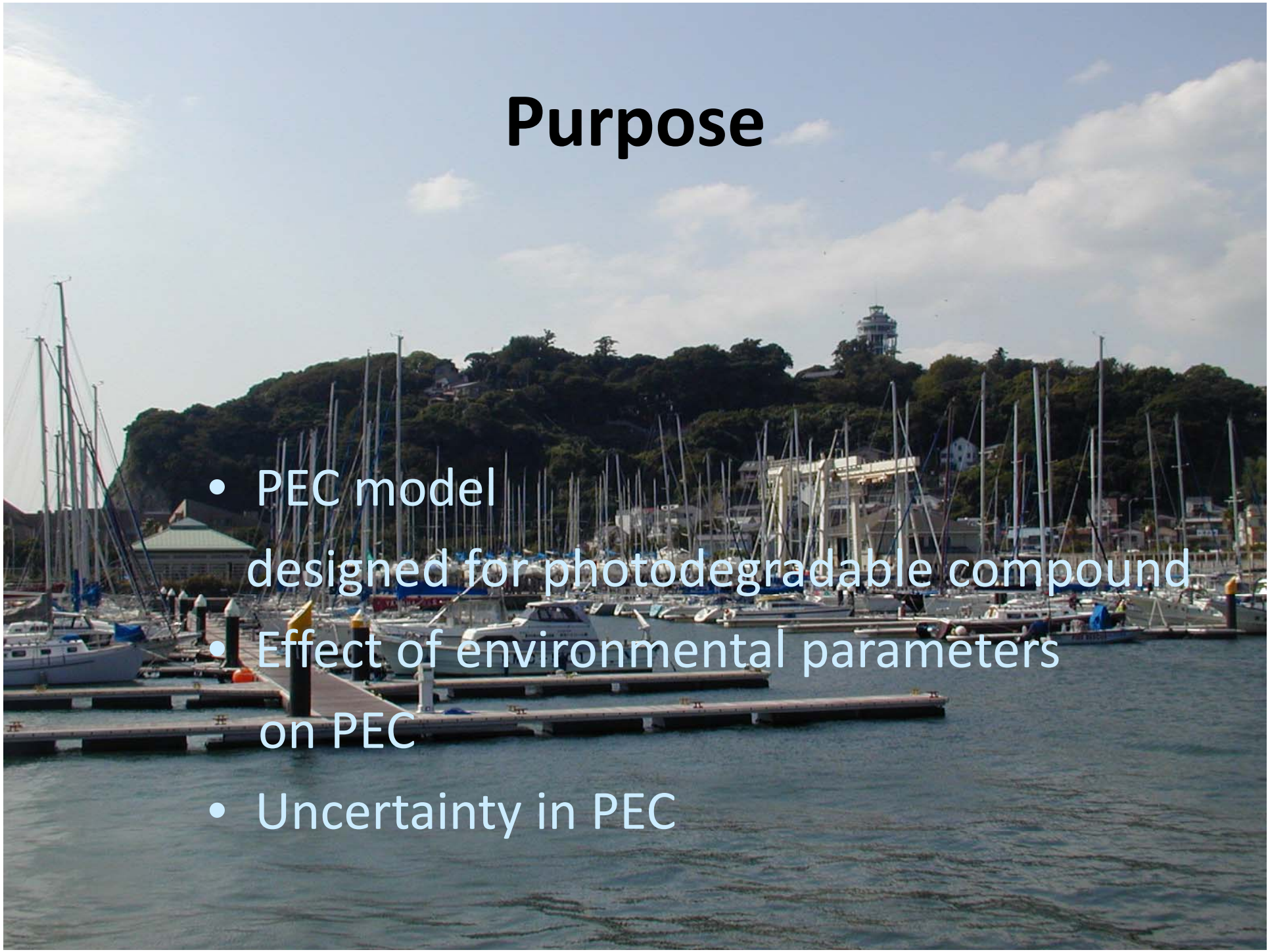


Purpose

- PEC model designed for photodegradable compound
- Effect of environmental parameters on PEC
- Uncertainty in PEC

Fate Processes

- transportation with water flow,
- diffusion droved by the concentration gradient,
- leaching from the paint,
- photolysis by the sun light,
- hydrolysis,
- biolysis,
- adsorption onto the suspended matter

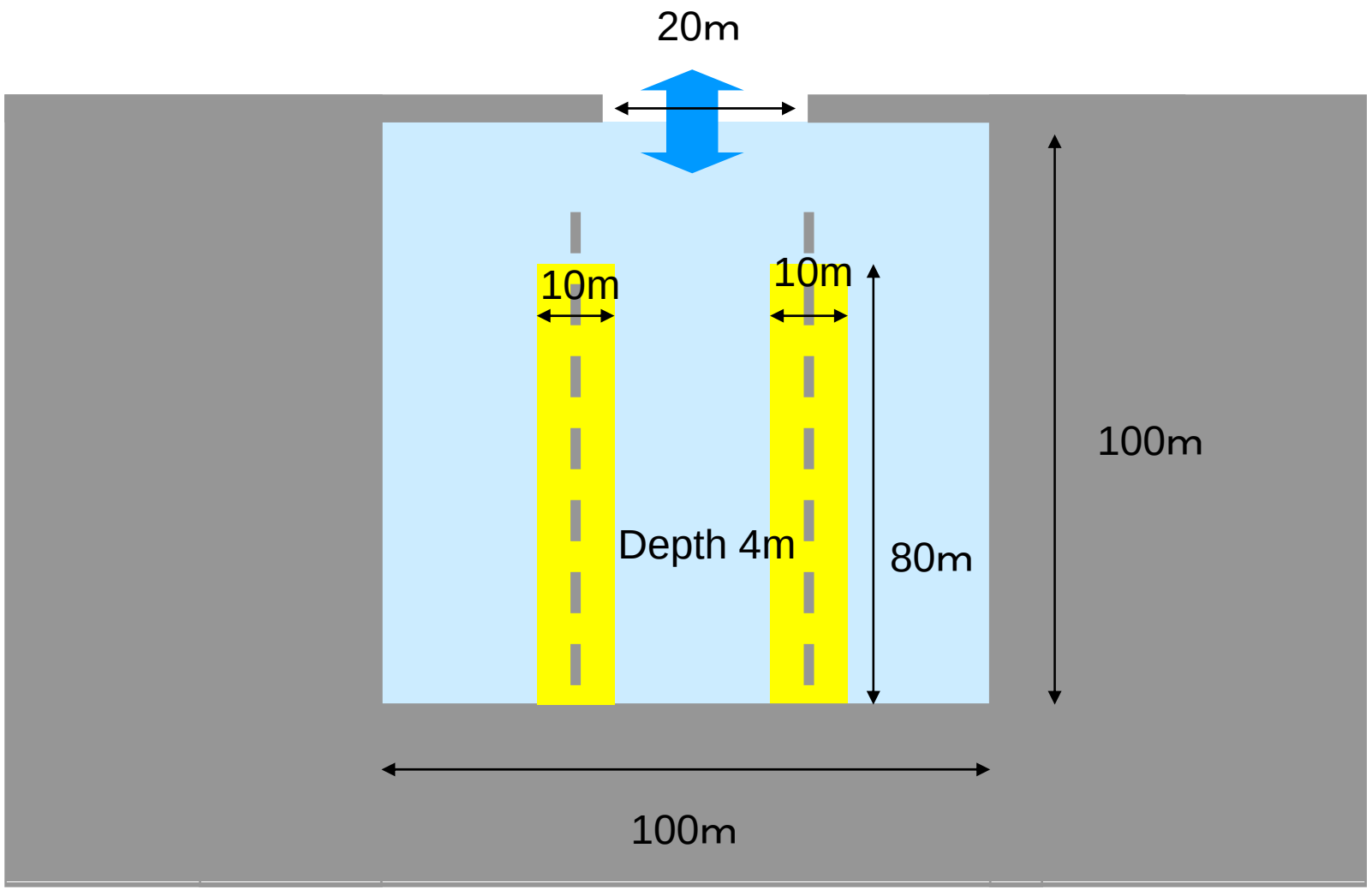
Special care on the photolysis

- a major decomposition process of modern antifouling agents in the aquatic environment.
- changes of the light intensity in the environment
- the model deals with the effect of

  sun light intensity change with time and penetration into the water column

Enoshima Marina

Marina Model



Photolysis Model

Photolysis：

Quasi-First Order Kinetics

$$dC/dt = -kC$$

Rate Constant for Photolysis：

Proportional to Light Irradiation Intensity

$$k = \alpha I$$

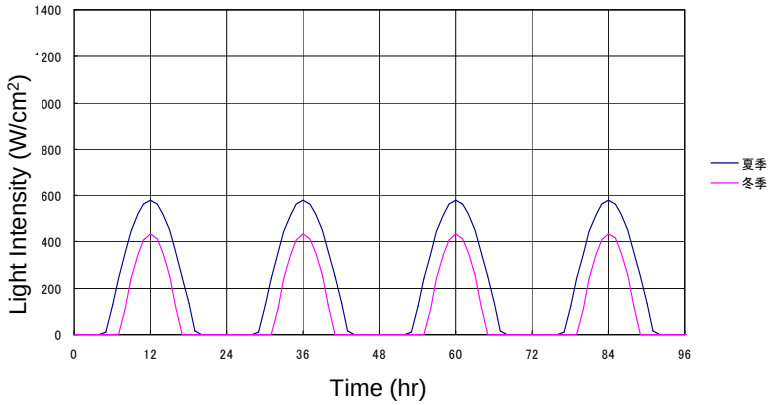
Sun Light Irradiation Intensity:

（Time, Day, Latitude, Weather)

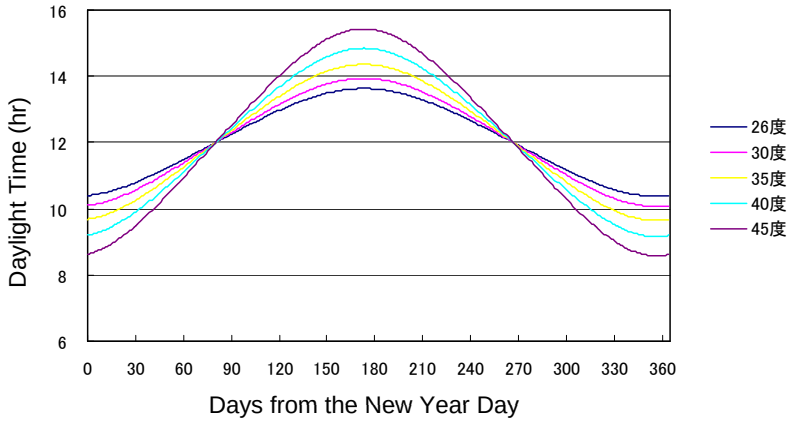
Light Penetration into water:

(Transparency, Wave Length, Suspended and dissolved matter)

$$I = I_0 \times 10^{-\beta z}$$



Light Intensity Change by day



Daylight Time Change during a year

Leaching and Diffusion Models

Leaching Rate

$$R_L = k_L A_S (C^* - C)$$

R_L : Leaching Rate (g/m^2)
k_L : Leaching Rate Constant (m/sec)
A_S : Leaching Surface Area (m^2-ship hull/m^2)
C^* : Saturation Concentration of AF(g/m^3)
C : Concentration of AF(g/m^3)

Diffusion

(Horizontal, Vertical)

$D_{e,x}\partial C/\partial x$,
$D_{e,z}\partial C/\partial z$

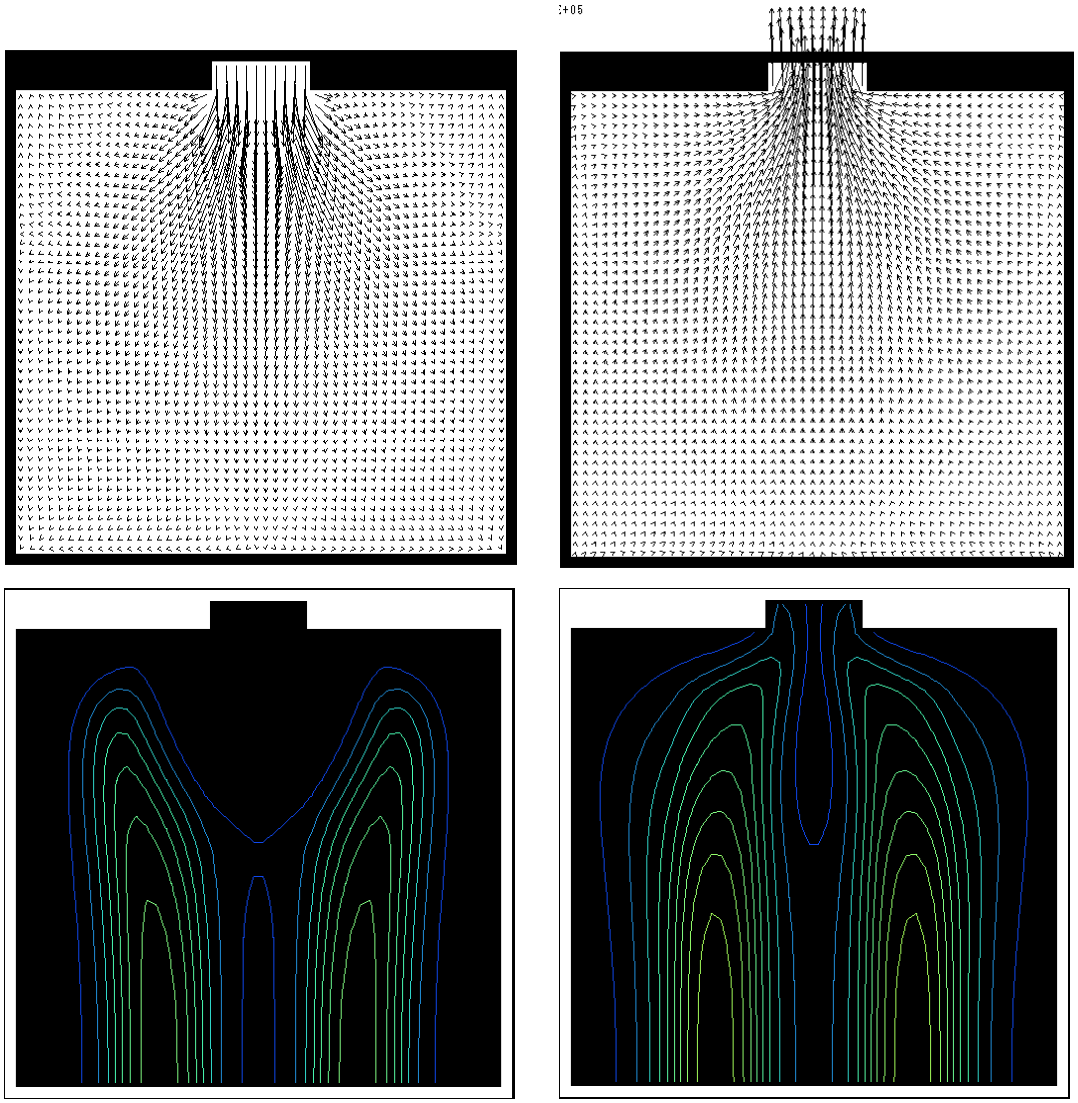
Water Flow

3D Numerical Analysis

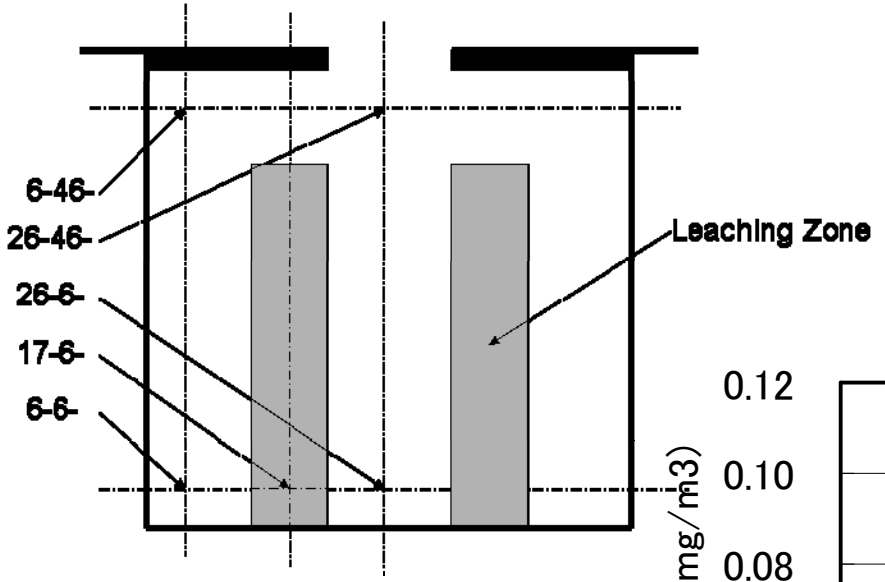
Reference condition

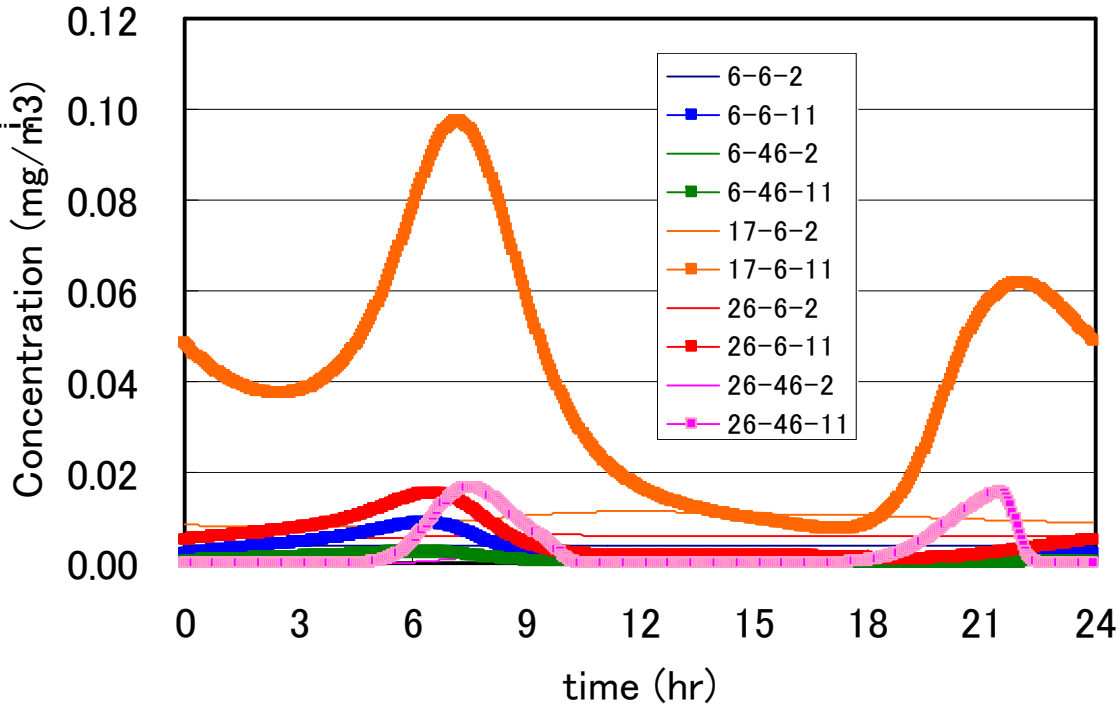
Tide difference	1m
Tide at 0 a.m.	Mid. Up tide
Horizontal effective diffusion constant	0.0001m^2/sec
Vertical effective diffusion constant	0.000001m^2/sec
Half life by photolysis	2220sec（37min）
At sunlight intensity	188W/m^2
Latitude	35N
Day	midsummer day
Weather	sunny
Transparency of the water	1m
Saturation concentration	4000mg/m^3
Leaching rate constant	6×10^{-9}m/sec

Water Flow and Concentration Profile

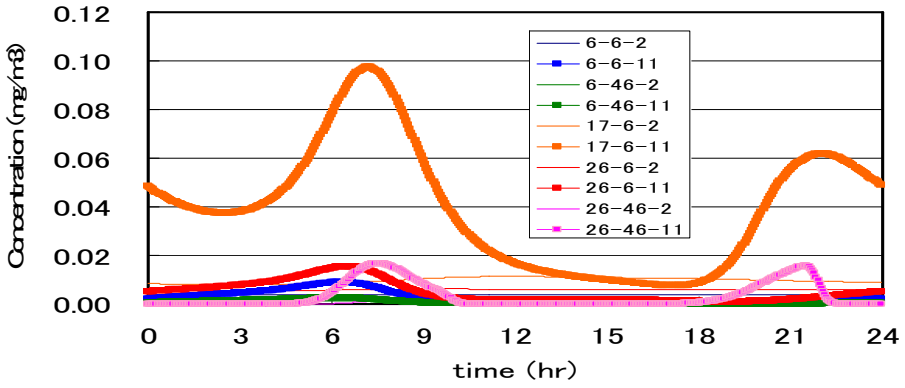


Calculation result

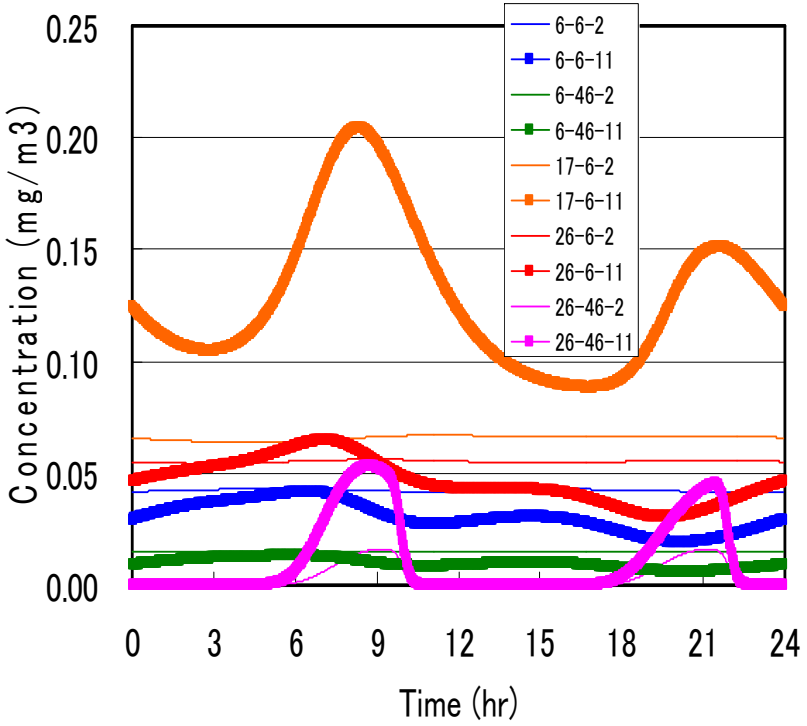




Case study
Half life period the photolysis

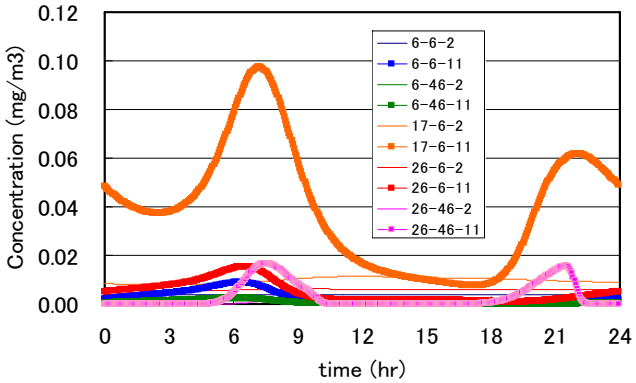


37min.

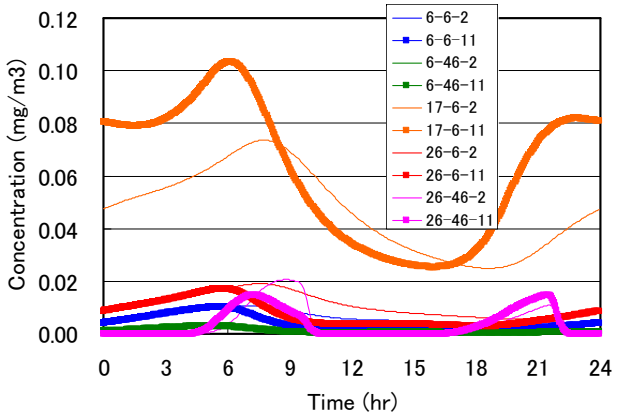


185min.

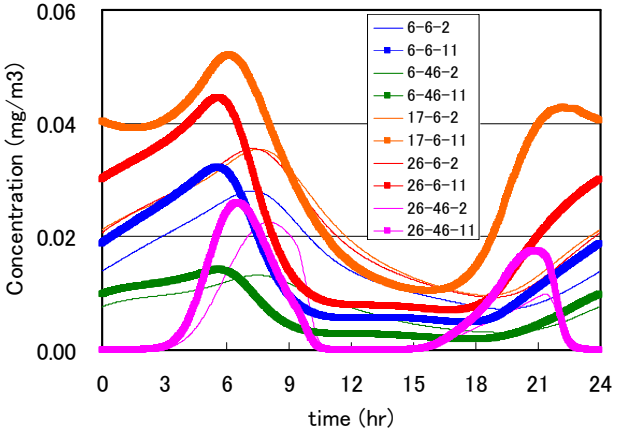
Case study
Effective Diffusion Coefficient



Reference

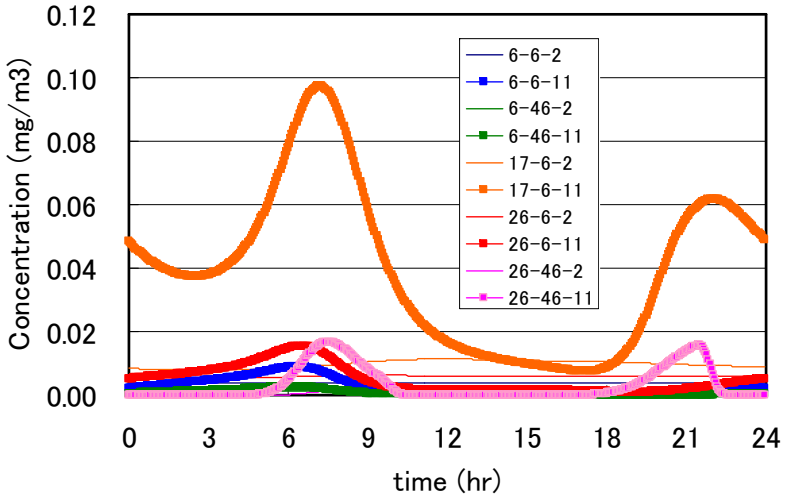


Vertical diffusion coefficient *10

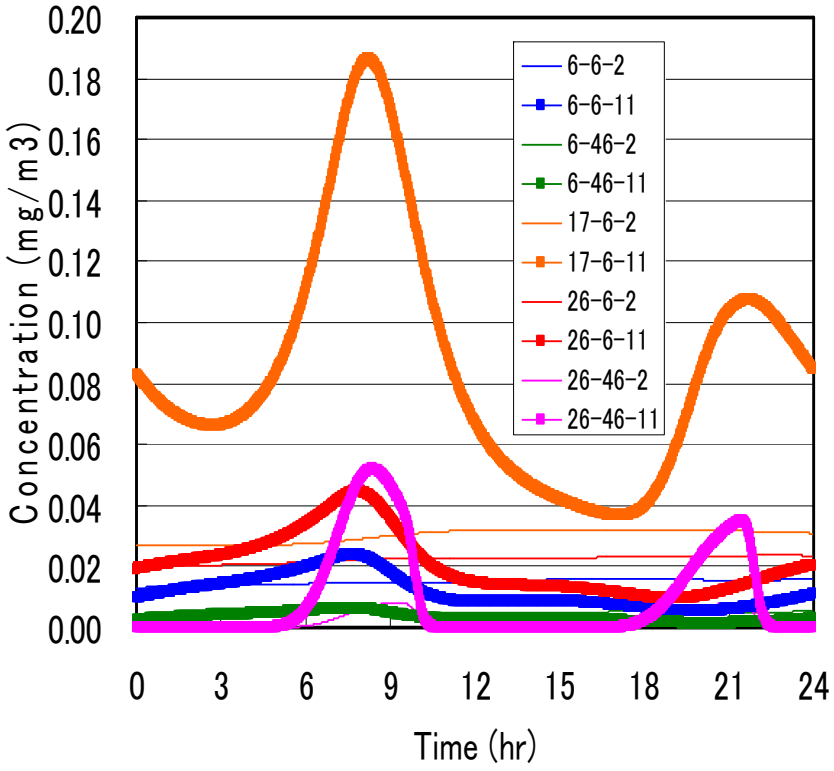


Vertical diffusion coefficient *10
Horizontal diffusion coefficient *10

Seasonal Change

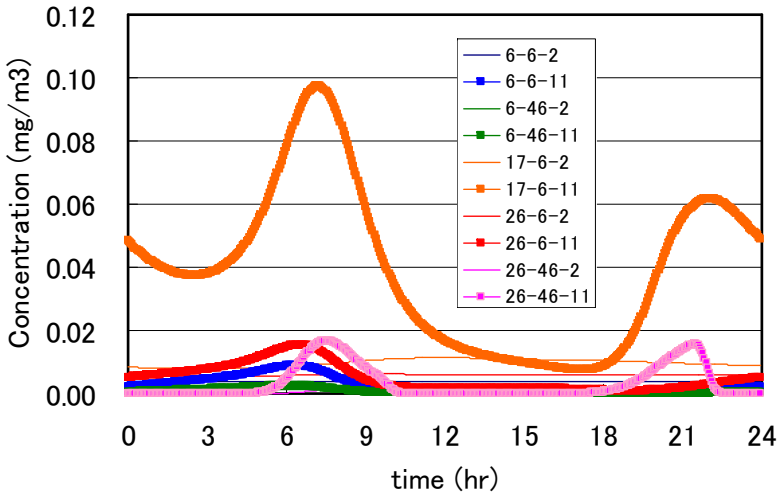


Summer

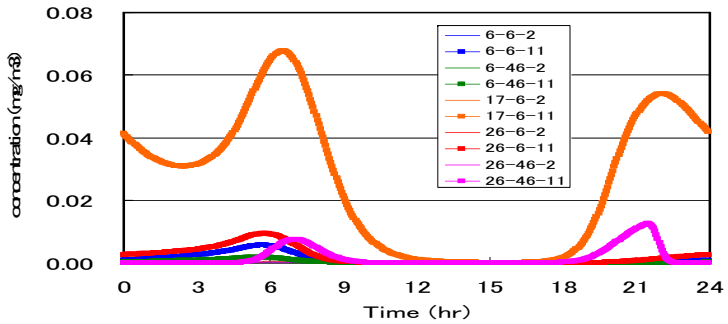


Winter

Transparency of Water

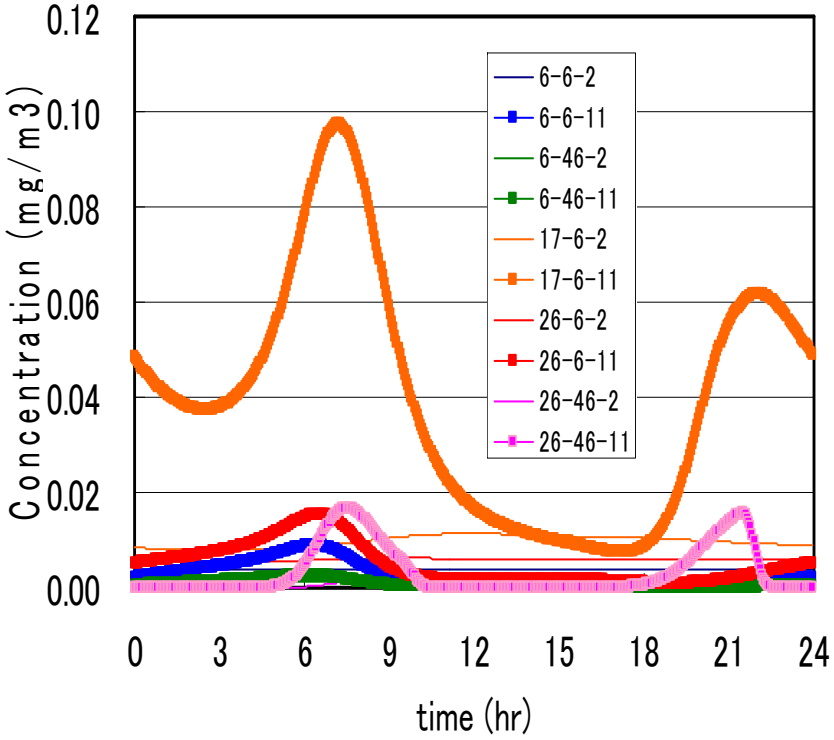


Transparency : 2m

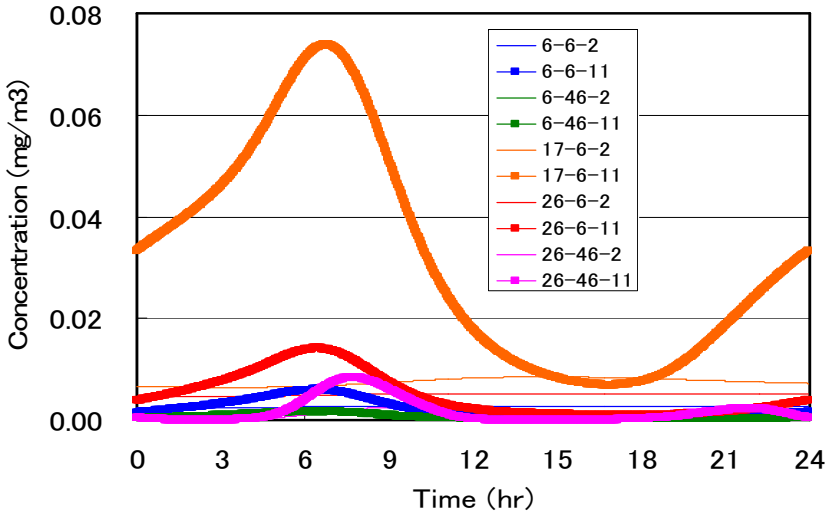


Transparency : 5m

Range of Tides

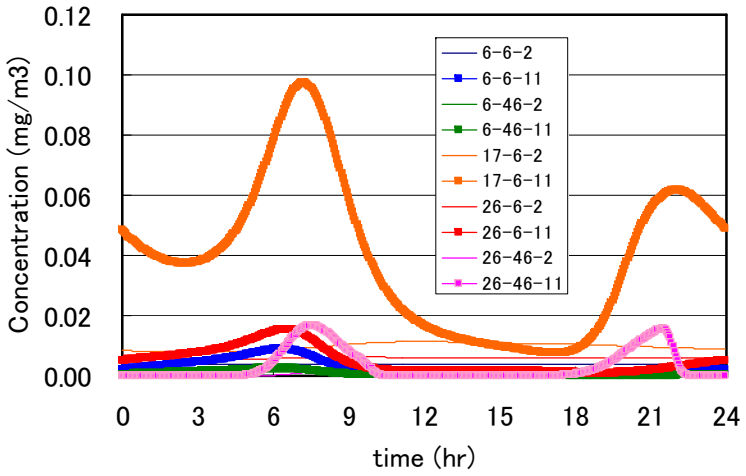


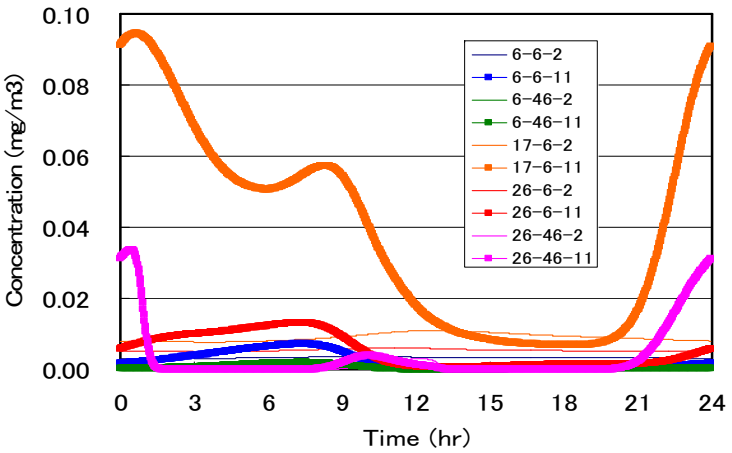
1.0m

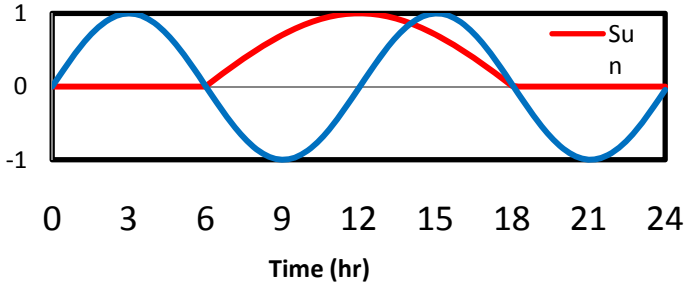


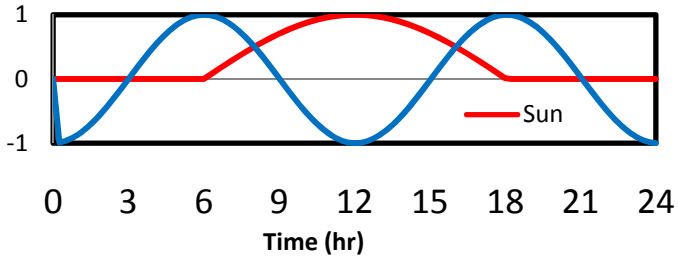
0.2m

Phase Difference between Sun and Tide









Conclusion

- Model calculation results show concentration profile change with time and location.
- Some of the results were very sensitive to environmental parameters.
- The values for the parameters could be changed by time, season, weather and geographical conditions.
- It implies uncertainty in the environment concentration prediction and monitoring.

Conclusion

- It suggests that it is essential to evaluate adequately the environmental parameters, and to take proper sample representing the environment.

- What is the environmental Concentration to be predicted/evaluated?

- What is the realistic and meaningful worst case scenario?