Characteristics of Oxygen Consumption by Sediment under Hypoxic Condition in Enclosed Coastal Seas

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Abstract

Enclosed coastal seas are suffering from serious environmental problems which caused by hypoxic condition occurring at the bottom of sea during summer season. Although many restoration technologies for supplying oxygen to the bottom of the sea are developed, it is necessary to understand the characteristics of sediment oxygen consumption (SOC) before applying these technologies in actual field because it is thought that the sediment oxygen demand increases under hypoxic condition. In this study, we carried out the field investigations for a year at Osaka bay by using a new chamber method which can measure SOC under hypoxic condition in order to examine the seasonal variations of SOC. In addition we conducted the laboratory experiment for examining the effects of biological and chemical factor on the SOC.

INTRODUCTION

Environment of Enclosed Coastal Seas

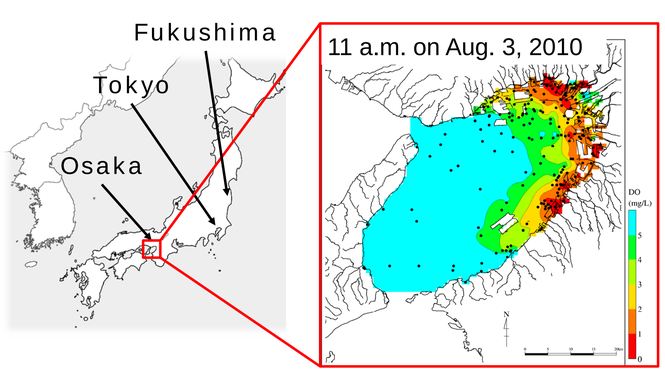

Fig 1: Spatial distribution of dissolved oxygen (DO) concentration of the bottom water in Osaka bay. Hypoxic bottom water appears widely at closed-off section of Osaka bay.

Fig 2: Impact of hypoxic water on the coastal environment. (↑Situation that crabs were escaping from hypoxic water. ↓Snapshot of seabed at closed-off section of Osaka bay.)

Restoration Technology

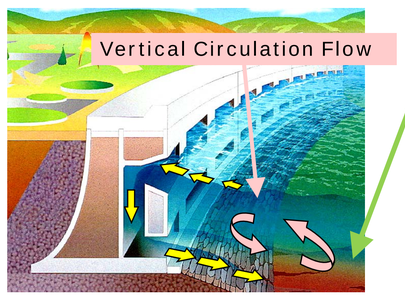

Fig 3: Proposed breakwater for generating vertical circulation flow (VCF breakwater, Endo, et al. 2006). Oxygen rich surface water is transported to the bottom of sea by the circulation flow generated in front region of the VCF breakwater.

Sediment under the hypoxic condition has
- Organic matter which contribute to biological SOC
- Reducing substance which contribute to chemical SOC

⇨ Increase of Sediment Oxygen Demand

How much oxygen we should supply to the bottom for restoration of the hypoxia ?

Purpose

In order to understand the characteristics of the sediment oxygen consumption,
1. Investigating the seasonal variations of SOC
2. Examining the effect of biological and chemical factors on SOC

FIELD INVESTIGATION

Investigation Summary

Investigation Period
- Once every two weeks in neap tide from April 2008 to April 2009

Investigation Items
- Sediment oxygen consumption
- Vertical profiles of water quality (DO, Temperature, Salinity, …)

Fig 4: Photo images of around the investigation site. Strong stratification develops through the year because this site is at the mouth of Yamato river.

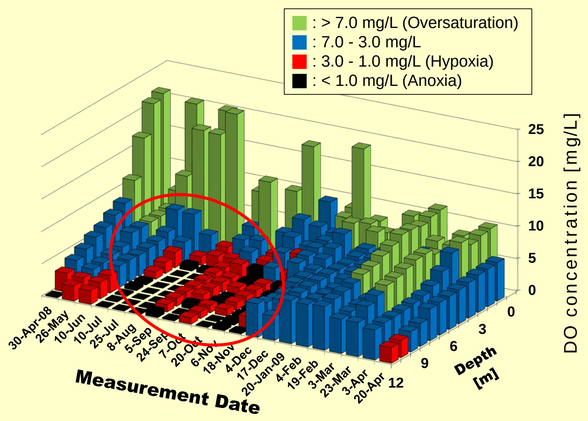

Fig 5: Seasonal variations of the vertical DO concentration profile at investigation site. Bottom water has become hypoxic condition from spring to autumn.

How do we measure the SOC ?

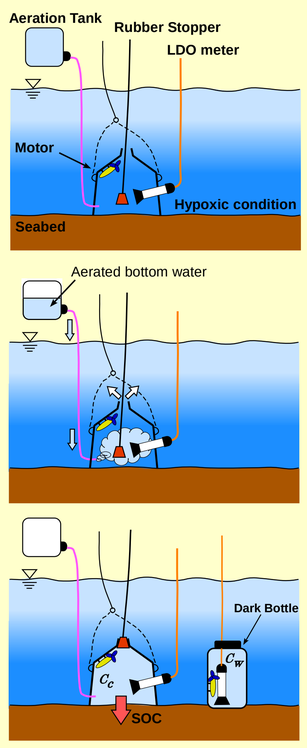

Fig 6: Apparatus and process to measure the SOC.
① Putting the chamber above the seabed keeping the water inlet open. ② Supplying aerated bottom water from the aeration tank into the chamber. ③ Shutting the inlet by rubber stopper after replacing the hypoxic water. ④ Measuring the SOC at every 5 minutes.

Result 1

● Temporal variation of SOC

$$\Delta SOC = -\frac{V}{A}\left(\frac{\partial C_c}{\partial t} - \frac{\partial Cw}{\partial t}\right)$$

ΔSOC : Oxygen consumption flux of the sediment every 5 minutes
V : Volume of the chamber
A : Area of base of the chamber
C_c : DO concentration in the chamber
C_w: DO concentration in the dark bottle

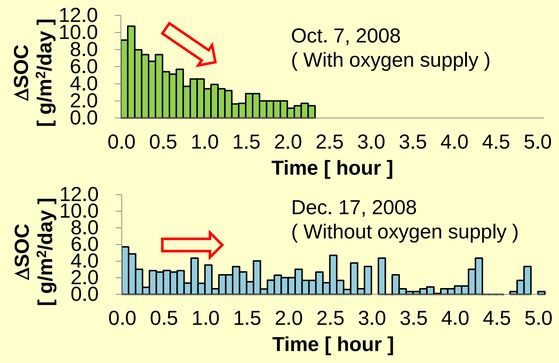

Fig 7: Time variations of ΔSOC which were measured on Oct. 7, 2008 and Dec. 12, 2008.

Result 2

● Seasonal variation of SOC

$$\Delta SOC = a \cdot C_c + b$$

a : the variable depending on chemical reaction
b : the variable depending on biological reaction

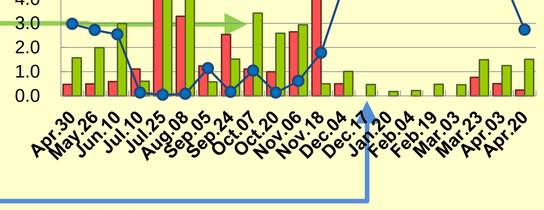

Fig 8: Seasonal variations of the variable a and b related to SOC and the bottom water DO concentration (C_b). Both variables become larger in hypoxic season than in winter.

EXPERIMENT

Experimental Setup

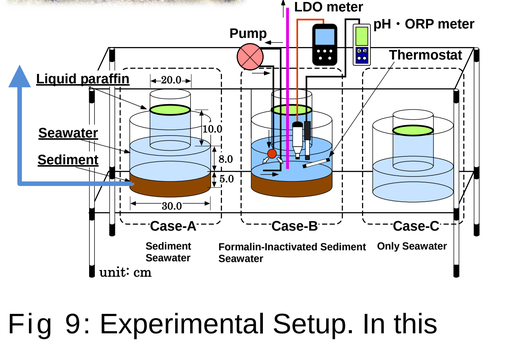

Fig 9: Experimental Setup. In this experiment, we prepared
(A) sediment and seawater
(B) formalin-inactivated sediment and seawater
(C) only seawater

Experimental Condition

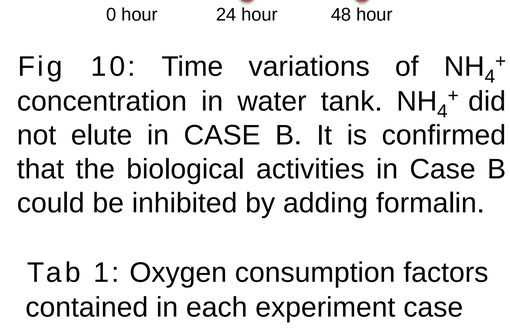

Fig 10: Time variations of NH_4^+ concentration in water tank. NH_4^+ did not elute in CASE B. It is confirmed that the biological activities in Case B could be inhibited by adding formalin.

Tab 1: Oxygen consumption factors contained in each experiment case

		Sediment		Seawater
		Chemical	Biological	Biological
CASE-A	Sediment+Seawater	○	○	○
CASE-B	Formalin-Inactivated Sediment + Seawater	○	×	×
CASE-C	Seawater	—	—	○

Result 3

● Effect of biological and chemical factors on SOC

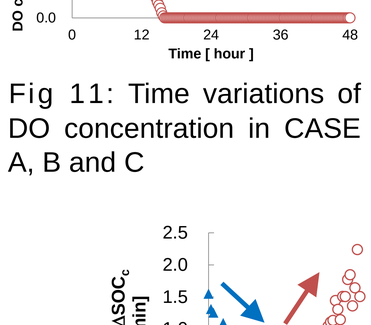

Fig 11: Time variations of DO concentration in CASE A, B and C

$$\Delta SOC_b = \left(\frac{\partial C_A}{\partial t} - \frac{\partial C_B}{\partial t} - \frac{\partial C_C}{\partial t}\right) \cdot \frac{V}{A}$$

$$\Delta SOC_c = \frac{\partial CB}{\partial t} \cdot \frac{V}{A}$$

ΔSOC_b: the biological SOC
ΔSOC_c: the chemical SOC
V : Volume of the water in the tank
A : Surface Area of the sediment
C_A, C_B, C_C : DO concentration in CASE A, B and C

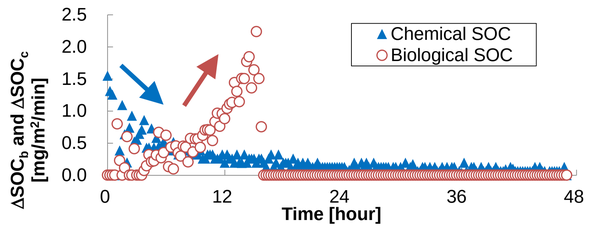

Fig 12: Time variations of the chemical SOC and the biological SOC.

CONCLUSIONS

1. The sediment oxygen consumption under hypoxic condition was varying with time while the sediment was consuming oxygen.
2. The sediment oxygen consumption in hypoxic summer season was larger than that in winter.
3. The oxygen consumption pattern of sediment under hypoxic condition was changing by chemical and biological factors.

REFERENCE

Toru Endo and Takaaki Shigematsu (2006): Numerical and Experimental Study of New Breakwater Promoting Vertical Circulation Flow, ICCE 2009, Vol.5, pp. 4,779-4,791.