Study on spatial and temporal variation in anoxic water and sulfide in Tokyo Bay

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Keywords	Anoxia, sulphide, blue tide, flat bottom, dredged pits, Tokyo Bay
Year and month	July, 2016

1. Introduction

Tokyo Bay is located in central Japan and is considered to be a typical enclosed bay. Due to the very high density of population and industry in the catchment area surrounding Tokyo Bay, increased nutrient loads have accelerated the accumulation of particulate organic matter around the head of bay (Wolanski, 2006). This is also one of the causes to drive Tokyo Bay usually suffering from excess phytoplankton blooming and subsequently hypoxia and anoxia bottom occur from spring to autumn. Reclamation activities for foreshore or for navigation purposes along coast of the head of bay in the past that have created coastal trenches with a various spatial scales. Waters in these dredged pits are considerably stagnant and hypoxic or anoxic water appears with high frequency.

One of phenomena is blue tide when formation of sulfur from oxidation of a huge amount hydrogen sulfide in the bottom waters is produced during decomposition of organic matter under anoxic condition combined with upwelling of oxygen-depleted bottom water induced by northeast wind-driven circulation at the inner of Tokyo Bay, sometimes affects seriously to aquatic communities of animals across large zones. Hence, it is necessary to understand variation of anoxia and sulfide related to blue tide phenomenon to reduce hypoxia and anoxia in Tokyo Bay.

1.1 Background and Purpose of the Study

There were many researchers pointed out characteristics of hypoxic waters in Tokyo Bay with considerable efforts to reduce this problems. (Komada et al., 2006) elucidated that hypoxia (DO $\leq$ 2 mg/L) presented continually at bottom in Tokyo Bay from April to October but it tended to decline in late June and early September in 2004. However, it needs more studies to specify more specifically on temporal and spatial variations of anoxia in which dissolved oxygen concentration is almost zero.

Several researches reproduced total sulfide processes when anoxic waters appear and evaluated preliminarily contribution of total sulfide released in flat bottom and dredged trenches (Sasaki et al., 2007). Nevertheless, improvement of sulfide reproduction is required to estimate more accurately these contributions.

This research aims to reach the following specific objectives:

(1) To identify the sources and to estimate the amounts of anoxic water and total sulfide in dredged pits, navigation channels and flat bottom

(2) To reproduce seasonal variation in anoxic waters and total sulfide using numerical model

(3) To propose remedies for reducing impact of blue tides.

2. Methods

2.1 Field observation

Four field surveys have been carried from July to September in 2015 covered almost the inner Tokyo bay, especially dredged pit areas and navigation channels. Such a number of water quality factors are salinity, water temperature, DO, sediment sampling recorded.

2.4. Numerical model

Mike 3 Eco Lab Model is used for reproducing hydrodynamics and water quality in Tokyo bay. The simulation period is from 2014 to 2015 to create comprehensiveness of the process. A coarse rectangular mesh with resolution of 450 meter is applied for calculating simultaneously with a fine structure gird of 150 meter enclosed major domain and 30 layers with 1 meter thickness for both meshes.

A data set has been collected for setting up model as follows: River discharge (flow rate); Weather (solar radiation, precipitation, wind, relative humidity, air temperature, cloudy cover); Open boundary condition (elevation, sea temperature, salinity). An ecological cycle to describe the processes of ecology in Tokyo bay (as shown in Fig. 1) is used in simulation. Seven variables dominate the phenomenon that are phytoplankton (PPL), detritus (DET), sediment (SED), dissolved oxygen (DO), phosphorus (PO4), hydrogen sulfide (H2S), sulfur .

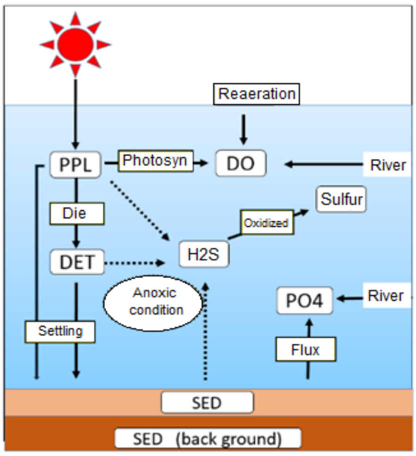

Figure 1. Ecological processes for Tokyo bay

In addition, data of salinity, sea temperature, dissolved oxygen at points of Kawasaki, Chiba Port, Chiba Light Beacon, Urayasu were also dowloaded for verifying the results between model and measurement.

3. Results and Discussions

3.1. Identification of anoxia

Results of field surveys reveal that anoxia would appear widely across flat bottom areas (Fig.2). More specifically, anoxia focused on central flat bottom enclosed navigation channel. Kawasaki flat bottom generally appeared hypoxia while anoxia just occur rarely with small scope.

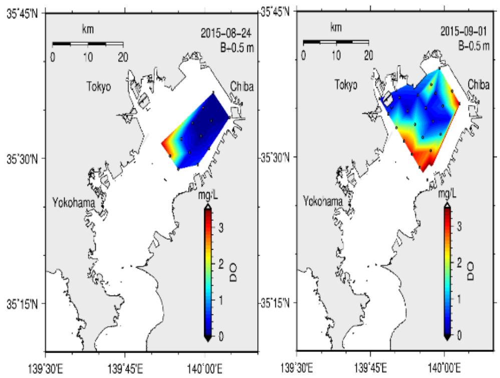

Figure 2. Measurement of DO on August 24 and September 1, 2015

On the other hand, there is a depletion of oxygen concentration from surface to bottom in these dredged pits (Fig.3 and Fig.4). In particular, all field investigations expose that anoxia mostly appeared at bottom in both dredged pits. Anoxic water layer tended to expand from the bottom to near surface layer on blue tide days (August 24 and September 1).

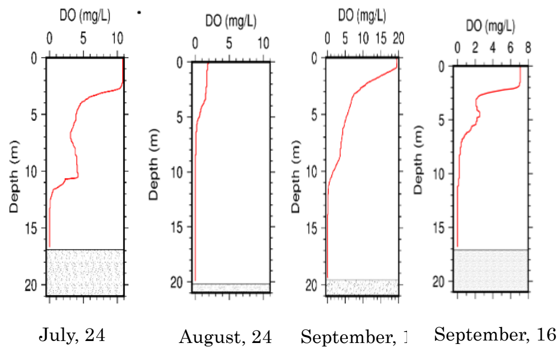

Figure 3. Field surveys results of DO in off-

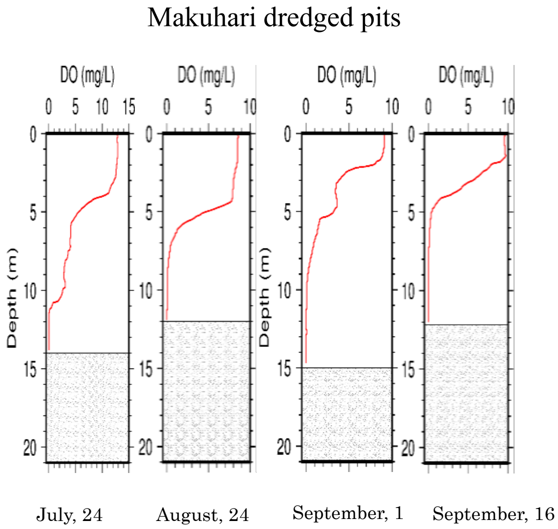

Figure 4. Field surveys results of DO in off-Urayasu dredged pits

Results from monitoring stations in Tokyo Bay reveal that anoxia appears later and disappears sooner while hypoxia usually occurs sooner and vanishes later. Anoxic bottom waters normally emerge from May to early November. Dredged pits or navigation channel would be significant anoxic water sources. From June to September anoxia on surface may develop frequently. Anoxia generally occurs seriously in July and August. Beside that model also shows well reproduction of anoxia process (Fig. 5).

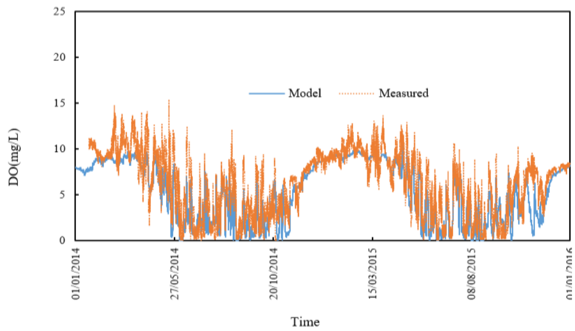

Figure 5. Bottom DO measurement and model at Chiba Port Station

3.2. Sulfide

All field surveys results of total sulfide determined that amount of total sulfide emitted from flat bottom at low level (Fig. 6).

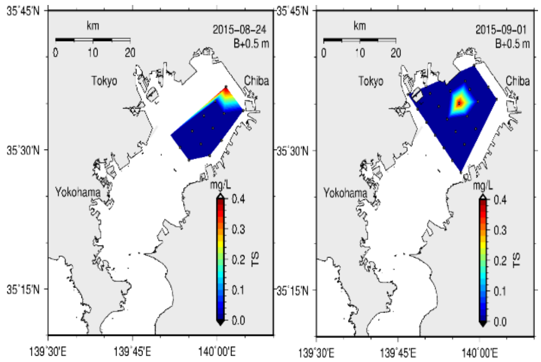

Figure 6. Measurement of total sulfide on August 24 and September 1, 2015

In a comparison, hydrogen sulfide concentration in dredged pits is much higher than in flat bottom especially when blue tide occurs. Observed results also illustrates the gap of total sulfide released in bottom in off-Urayasu and off-Makuhari. In off-Makuhari dredged pit, total sulfide concentration reached nearly 60 mg/L on August 24 (Fig.7). By contrast, in off-Urayasu dredged pit total sulfide was much lower (Figure 8). Due to off-Makuhari is deeper than off-Urayasu, anoxia thus developed more seriously in off-Makuhari leading to more release of hydrogen sulfide especially on 24/8 and 1/9. Similarly, model reproduced well variation of sulfide.

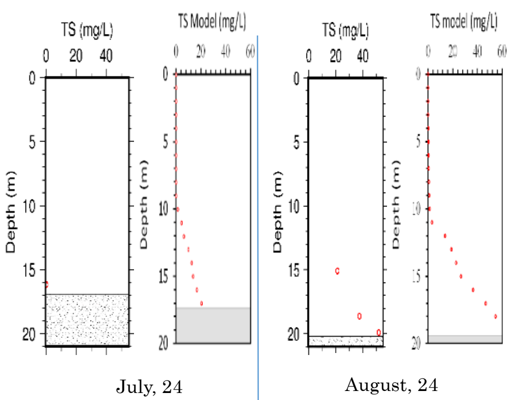

Figure 7. Sulfide between field observation and model in off Makuhari

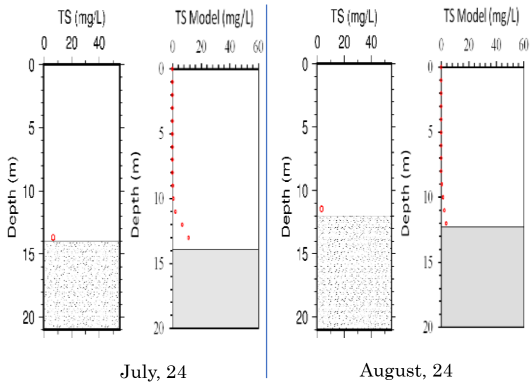

Figure 8. Sulfide between field observation and model in off Urayasu

To examine contribution of total sulfides between flat bottom and dredged pits, time series of total sulfides are extracted from model. Although released total sulfide concentration in flat bottom is much lower than dredged pits, however entire area of flat bottom is much larger than dredged pits. Fig. 9 below compares total sulfides released in flat bottom and dredged pits. The graph shows fluctuation in flat bottom while total sulfides in dredged pit accumulates from May before declining from late September. Because anoxic bottom water appears in dredged pit more frequently than in flat bottom resulting fluctuation and accumulation of total sulfides in flat bottom and dredged pits respectively. It can be seen that total sulfide begins to bloom from May when anoxic water develops and flat bottom might emit total sulfides more than in dredged pit.

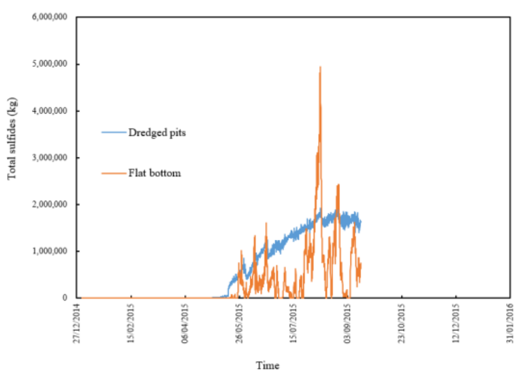

Figure 9. Estimation of total sulfide in dredged pit and flat bottom

3.3. Effect on blue tide

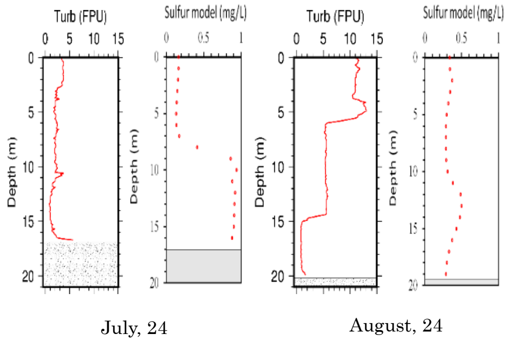

Figure 10. Sulfur model and turbidity in off Makuhari dredged pit

Maximum of sulfur in a water column is at the interface between anoxic layer and oxic layer. When northeast wind blow (blue tide occurs), upwelling will bring sulfur particles to upper layer caused high turbidity on surface.

4. Conclusions

This study has shown that anoxia appears later and disappears sooner while hypoxia usually occurs sooner and vanishes later. Dredged pits and navigation channels are where anoxic waters usually occur. Tidal flat bottom also encounters anoxia less frequently than dredged pits and navigation channels. Results between surveys and reproduction are quite appropriate. Filling up these dredged pits would be an effective solution to reduce spatial expansion of hypoxia and anoxia in Tokyo Bay.

5. References

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