Numerical Modeling of Particulate Mercury Dynamics in Coastal Environment: Case Study in Minamata Bay, Japan

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（沿岸域環境における粒状態水銀動態の数値モデリング：水俣湾におけるケーススタディ）

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論　文　内　容　の　要　旨

Minamata disease was a one of huge tragedy that claimed many victims in Japan in 1956. The disease was caused by mercury contamination which disposed by a chemical factory to the Minamata Bay. The inorganic mercury that had been used for acetaldehyde formation, were disposed and this compound could transform into methylmercury (MeHg) compound. MeHg is the most toxic compound of mercury which accumulates in the marine organism and also human who consumed it. Around 40,000 people were reported affected by this disease, which attacked central nervous system. The MeHg compound itself is mostly found at sediment in the bottom layer. Therefore to solve this problem, Japanese government had conducted remediation project to remove the contaminated bottom sediment around Minamata Bay. Bottom sediment which contained more than 25 ppm of mercury was removed and reclaimed to the enclosed area in the bay.

Many years after the project, the transport of particulate mercury from Minamata Bay to the outer side of the bay was reported. The transport was expected came from the remaining mercury in bottom sediments in Minamata Bay which was not been removed (less than 25ppm concentration). Mercury was found in the Yatsushiro Sea, the western sea from the bay, and also some Minamata disease victim were found in Amakusa region in the western part of the Yatsushiro Sea. Numerical simulations and field measurement of sediment transport from Minamata Bay also have shown that there is transport to the Yatsushiro Sea. Yano et al. (2014) had conducted the sediment transport simulation, and showed result of the western, southern, and northern transport due to the flow. However, the description of the bay from their simulation was not precise yet. In order to get better and accurate result, this research suggests using a better resolution grid of the bay and other considered model parameters. In addition, it is also necessary to understand mercury fate in sediment, and also the mechanism of its transport in the coastal environment.

The present research is divided in some chapter in this thesis, and described as follow:

Chapter 1 explains about research background, research problem, research objectives, the scope of the research, and also the overview of the thesis as an introduction.

Chapter 2 explains about mercury dynamics in the global environment, including its cycle. Furthermore, mercury problem includes Minamata disease outbreak and also the solution are described. The three-dimensional numerical model of hydrodynamics and sediment transport by Delft3D is also presented.

Chapter 3 presents numerical simulation using a new grid system and additional layers for simulating sediment transport in Minamata Bay. The rectangular variable grid is divided into three different grid sizes, namely, 250m (original size), 125m, and the finest 62.5m. The sediment transport and tidal flow are calculated. In this chapter, the previous simulation by Yano et al. (2014) is compared with the result of the new variable grid system. The results show that by adapting the additional layers and the finer grid, there is a northward movement of sediment around the coastal area. From six months simulation, it is showed that most deposit areas that generated by barotropic flow are the western and southern area from Minamata Bay and baroclinic flow moves the sediment to north and finally dispersed it to outside area of the southern Yatsushiro Sea.

Chapter 4 discusses the impact of the reclamation project in mercury highly-contaminated sediment in Minamata Bay. Here also tidal flow and sediment transport are simulated and applied in two different topography on before and after reclamation around the bay. The change of hydrodynamic condition inside of the bay due to the remediation project gives a slight change in sediment transport pattern. It is estimated that the sediment after the reclamation can transport slower than before it because of change of its magnitude of velocity above the seabed. It is clarified that a change of the amount of bottom sediment which can be re-suspended in the bay due to the topographical change can also affect the pattern. Also, this result suggests that the southern part of Yatsushiro Sea can be influenced by sediment contaminated by higher Hg included before the reclamation project.

Chapter 5 simulates the effect of the damage of reclamation walls in Minamata Bay. The walls that built more than 25 years ago, when the remediation project has been conducted, is feared to be collapsed and leaked highly contaminated mercury from the reclamation area to the bay. In order to predict an influence of sediment leakage, the numerical simulation of sediment transport and suspended solid (SS) distributions from the reclaimed wall area to the bay are conducted. We assume a part of the wall in the north and south part collapsed and for one day in rainy season, the highly contaminated sediments including mercury are released to the bay. SS distribution to the bay is more significant when the south part of reclamation wall collapses than the north part. In the upper layer, when the low tide occurs, barotropic and baroclinic flows move SS to southwest direction entering the bay, and at high tide, the SS can be distributed around the northern area. From the result, in the upper layer, it can be assumed that baroclinic flow is significantly distributing SS to Minamata Bay, meanwhile in the deeper layer barotropic and baroclinic flow almost have a similar contribution in transporting the sediment from reclamation wall to the bay.

Chapter 6 evaluates the relationship between particulate total mercury (P-THg) in seawater and suspended solids particle size distribution in Minamata Bay. We used a cluster analysis by the Ward method, attempted to judge the best grouping using the entropy method, and confirmed statistical significance of the relationship between each group and P-THg concentration with both of Bartlett test and Kruskal-Wallis test. The results show that the most optimal group number of SS particle size distribution was determined as six groups, also statistically significant correlation between the P-THg concentration and SS particle size distribution was seen and from the present relationship between particulate THg concentration and SS particle size fraction, that particulate THg depends on source of SS and mixing condition with SS from rivers and other possible sources.

Chapter 7 concludes all chapters in this thesis and also proposes some recommendation for future works.