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Characteristics of Mixing and Thermal Stratification in a Small Shallow Lake

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Mixing process is one of the important characteristics of a water body because it affects the distribution of water quality variables in the water body. In closed water bodies which the inflow and outflow are usually small, vertical transportation based on the formulation of water temperature stratification, the problems with water quality due to the inhibition of mixing easily occur, especially the problems become serious in shallow water bodies. The main reasons that drive the formulation and disappearance of water temperature stratification are mechanical disturbance caused by the acting of wind, or solar radiation in daytime, thermal disturbance due to cooling at night. Clarifying the processes of formulation and disappearance of stratification response to these two kinds of disturbance is very important for management and improvement of the environment in the water bodies. So, in this research, a shallow closed water body (Shikinawa Lake) located in Fukuoka Prefecture, Japan with the overgrowth of aquatic plants was targeted for field observation and quantitative discussion on the processes of formulation and disappearance of the thermal stratification.

Through the investigation on the formulation and disappearance of thermal stratification by field observation in a small shallow lake, effects of thermal convection and wind-induced flow to the development of mixing layer in the lake were clarified. Field observations were conducted to get water quality and the related data in four different meteorological patterns. The observed data showed that profiles of the water temperatures were cyclic from the formation of a strong stratified layer in the heating time due to solar heating in daytime to the formation of a mixed layer based on thermal convective flow during cooling time at night. Wind induced flow allowed circulation and helped mixing process of the lake water. Wind induced flow based on wind stress acting on the water surface, and the action of the thermal convection caused by the heat release from the water surface was analyzed in order to understand deeper development and action of turbulent flow in mixed layer. All the of the results pointed out that in most of cooling time, thermal convection was much greater than water friction velocity caused by wind shear stress. Wind action played an important part in horizontal turbulent mixing. Low values of Wedderburn number, which are lower than 1.0, showed that strong wind period helped circulation process in lake, especially in near-to-surface layers.

Calculated results also found that thermal convection velocity component due to cooling process was the main force that dominated mixing process in the lake, as turbulent entrainment induced by thermal convection Ef could be presented as exponential functions of over-all Richardson number. On a contrary, this relationship could not be found when estimating entrainment rates Ew due to wind action.

Beside effects of meteorological factors as external forces, variation of water depth and coverage of aquatic plant on the water surface were also importance factors that affected strongly thermal regime of the lake's water. Some significant effects of combined external forces on the lake's thermal characteristics and water quality were found.

Results concluded from this research are very useful for understanding and simulating thermal regime inside a closed, small, and shallow water body, including surface exchange at the air-water interface, mixing, convection and stratifying process in lake's circulation.