VERTICAL MIXING BEHAVIOR OF SHALLOW STRATIFIED RESERVOIR USING DO

Saitama University Student Member ○Tulaja Gurung
Saitama University Regular Member Eiichi Furusato
Environment System Inc. Kazuhiro Ayukawa
Ryuku University Takashi Hirose
Japan Water Agency Hiroomi Imamoto

1. INTRODUCTION

Cyanobacterial bloom has become the major problem for dam reservoir management that deteriorates the recreational value of surface water and quality of drinking water supply. Furthermore, harmful effect on human health from toxins produced by these blooms have been reported (Falconer et al. 1994). The growth of these blooms is always governed by the hydraulic condition such as the stratification and mixing. Stratification stimulates the growth of bloom while mixing depress the growth by limiting the light availability (Smith and Jones, 2015). Thus, knowledge of mixing behavior of the reservoir for the reservoir management is important.

Mixing in reservoirs primarily depends on the meteorological condition of that area (Tuan et al., 2009, Kimura et al., 2017). During mixing period water column is characterized by homogenization of water quality (Fischer et al., 1979). Water is mixed vertically with most physical, chemical and biological constituents typically having nearly homogeneous concentration throughout the water column. Many studies have been carried out on mixing layer based on physical parameter of water such as temperature or density. Owing to the definition of mixing layer chemical parameter like Dissolved Oxygen (DO) can also be used to observe the mixing pattern. In this study, mixing behavior of shallow stratified reservoir influenced by the meteorological factors with respect DO variation is observed.

2. STUDY AREA AND METHOD

A mountain castle pond; Yamaghusuku (26° 22’ N, 126° 48.2’E) lies in Kume Island, a small island in 100 km west of Okinawa Prefecture, Japan. Water from this reservoir is mainly used for agricultural irrigation. This is a shallow reservoir with maximum depth 7.5 m and surface area 22,351 m^2. The catchment area is very small as compared to reservoir size, so the inflow and outflow discharge can be neglected. Thus, the reservoir can be considered as a closed water body.

The high-resolution micro profiler (hydrolab DS5 snode, multiparameter water quality analyzer) is used to measure the water quality that provides the data in 1cm depth interval in this shallow reservoir. Water temperature (WT), DO, Conductivity, Chlorophyll a, Turbidity and Redox Oxygen potential data are obtained from this micro profiler from the December 2016 to November 2017. Meteorological data were obtained from the Automated Meteorological Data Acquisition System (AMeDAS) developed by Japan Meteorological Agency (JMA) which is located about 2km away from the reservoir.

3. RESULTS AND DISCUSSION

Mixing in the reservoir starts as air temperature drops down and surface water cools, becomes heavier and sinks. The mixing is increased by the strong North east directed wind with peak speed 10.7m/s keeping the reservoir homogeneous throughout the depth at last week of December. Slight increase in temperature at the beginning of January (above 20°C) causes partial mixing which is followed by full mixing as temperature drops down to about 16°C after second week of January (see Fig 1). In the month of February, full mixing occurred only once for very short period, 3-4 days when the air temperature drops to the lowest 11.3°C with almost no sunshine. Dissolved Oxygen profile suggest partial mixing followed by stable but weak stratification in February.

By the end of March, temperature began to increase allowing solar heating to take effect and strong stratification starts to build. This stratification becomes strong with time as the temperature rises and wind remains calm in summer. Heavy rainfall and high velocity wind destroys this strong stratification in mid of June allowing full depth mixing for the short period. Strong stratification is observed in the month of July. From the dissolved oxygen data sharp nature of transition between the mixed upper layers and anaerobic hypolimnetic water column is noticeable. There is no transfer of oxygen across this transition zone. As the strong persistent wind starts with the beginning of August, the surface mixed layers start to deepen. July to November due to typhoon effect in this area full mixing events are occurred occasionally.

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Contact address: 225 Shimo Okubo, Sakura-ku, Saitama, 338-8570, Japan, Tel:048-858-3429, E-mail: tulaza.gurung@gmail.com

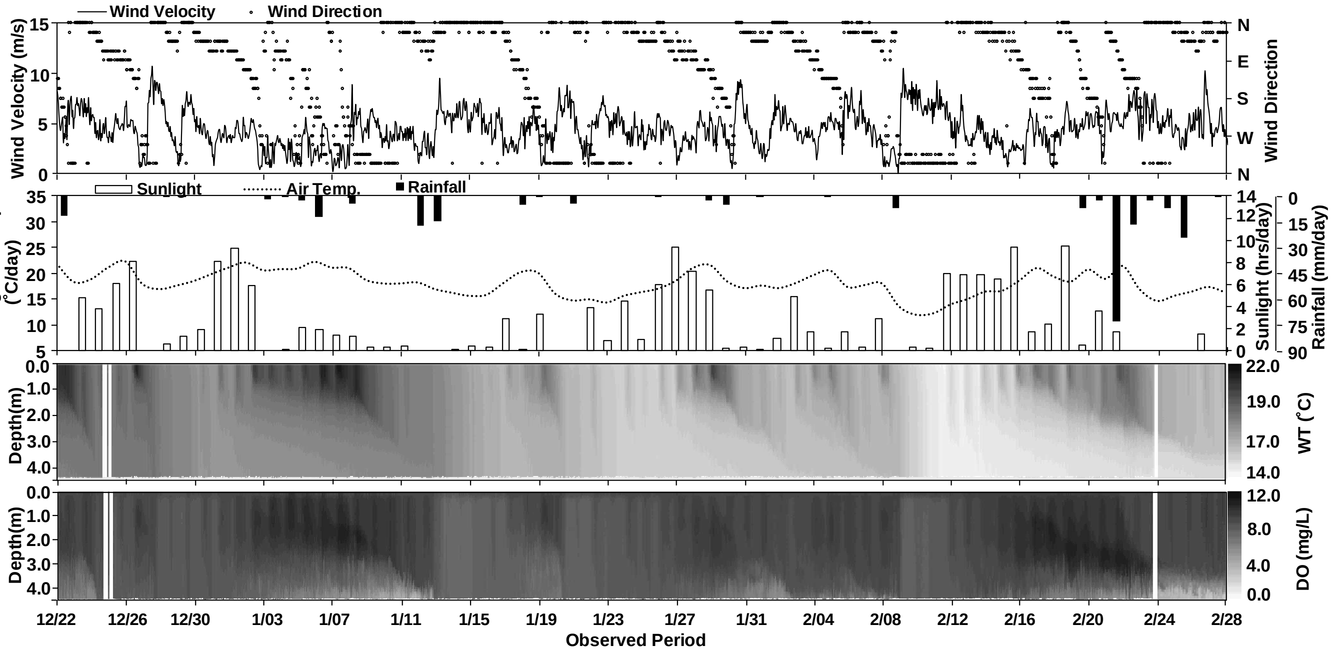

Fig.1 Temporal variations in vertical profile of WT and DO in local meteorological condition

The result shows that mixing pattern in the shallow stratified reservoir is greatly influenced by the meteorology (Tuan et al., 2017) of that area and remains stratified most the period due to warm climate. Extreme meteorological condition like typhoon cause the full mixing event in summer and autumn, (Kimura et al., 2017). During winter season also, full mixing is seen only at a times of low air temperature, below 18°C and sunshine hours (see Fig.1). This indicates that mixing is related to air temperature and sunshine hours which means heating/cooling as an external mixing force plays important role for the mixing. Strong and persistent wind deepens the surface mixing layers. Overall, air temperature appears to be dominant for mixing.

4. CONCLUSIONS

The field observation shows thermal cycle which effects the strength of stratification and thus the intensity of mixing is related to air temperature, sunshine hours and wind, even though sporadic events such as typhoon cause full mixing. Generally, full mixing is considered in winter season due to surface cooling resulting convective mixing. However, dissolved oxygen profile suggests that even in winter full mixing occurred few times for very short period. Stratification is seen throughout the year except for short period mixing in winter due to the high temperature characteristics of sub-tropical region even in a shallow reservoir.

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