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Low oxygen consumption in slow sand filtration by effective removal of floating algae

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ABSTRACT: Slow Sand Filtration (SSF) is a biological system to purify tap water. In this study, dissolved oxygen concentration and its diurnal changes were measured at three different SSF plants. Different treatments of floating algae were done in these SSF plants. The daily gross production rate was almost the same in there three plants. It was clear that the daily respiration rate at the Sodeyama plant was the lowest rate. The floating algae were effectively removed at this plant. Therefore, oxygen consumption by floating algae became minimal. The removal of floating algae reduces oxygen depression, even in the nighttime. Hence, it is effective remove of floating algae to make desirable filtrate water.

Key Words: floating algae, respiration, gross production, net production, slow sand filter, dissolved oxygen, oxygen production rate, scum outlet

Introduction

Slow Sand Filtration (SSF) is a biological system to purify tap water. The ability of SSF to purify water depends on the biological activity of algae, bacteria and small animals. Oxygen is provided by algal photosynthesis. Reduced substances (Fe^{2+}, Mn^{2+}, NH_4^+, etc) in raw water are oxidized in this system.

There is a slow downward current in a filter pond. Planktonic algae cannot grow in this pond. However, filamentous algae grows on the sand bed. After a while, a part of the algae floats to the surface of filter pond. In the case where, floating algae is not removed from the SSF pond, the algal biomass increases, and a large amount of oxygen is consumed during the nighttime. It was reported that undesirable filtrate water was produced due to the low oxygen concentration (Kojima 1983). In general, part of the floating algae is removed through a scum outlet.

When floating algae is effectively removed from a filter pond, algal respiration will be reduced. And the algae on the sand bed can receive much more solar radiation. Then algal photosynthesis actively occurs on the sand bed. Therefore, gross production and net production will increase.

In this study, dissolved oxygen (DO) concentration and its diurnal changes were checked at the different SSF plants (the Sodeyama plant, the Ishigaki plant and the Wakata plant) in order to evaluate the treatments of the floating algae. The treatments for the floating algae were done in two different ways. The most common method is removal of algae by a scum outlet. This can remove part of floating algae. The other method uses a gill net to remove the floating algae. This can completely remove the floating algae.

Study Plants

The Wakata purification plant is located in Gunma Prefecture. The Ishigaki purification plant is located in Okinawa Prefecture. In both plants, the treatment of floating algae is by scum outlets in the SSF ponds. The source of water for both plants is surface stream water which is passed through a sedimentation pond. The Sodeyama purification plant is located in Okinawa Prefecture. In this plant, the treatment to remove floating algae utilizes a gill net. The source of water is underground water.

Methods

The diurnal change of DO in inflow water and in outflow water (filtrate water) was measured at each plant. The daily respiration rate, gross production rate and net production rate were calculated from the diurnal change of DO concentration and the current velocity.

DO concentration was measured by the Winkler Method. The DO concentration of outflow water is influenced by the activity of the biological community, and its concentration varied with current velocity. Oxygen production rate per unit area per hour is given as follows:

Oxygen Production Rate ($g \cdot m^{-2} \cdot h^{-1}$) = (DOout − DOin) × v

DOout : DO concentration of outflow water ($mg \cdot l^{-1} = g \cdot m^{-3}$)

DOin : DO concentration of inflow water ($mg \cdot l^{-1} = g \cdot m^{-3}$)

v : current velocity ($m \cdot h^{-1}$)

The above shows the apparent oxygen production rate per hour. This is the net production rate, and the graph of rate against time showed a sine curve form. The lowest rate is observed before sunrise. This rate was the oxygen consumption (respiration) rate for the whole community in the SSF pond. In this paper, it was assumed that this oxygen consumption rate continued throughout the day. Algal photosynthesis caused the difference between the apparent oxygen production rate and the oxygen consumption rate.

The daily respiration rate, gross production rate and net production rate can be calculated from the diurnal curve of apparent oxygen production rate per hour.

The daily respiration rate was 24 times that of the oxygen consumption rate per hour. The daily gross production rate was calculated by the difference between apparent oxygen production rate and the oxygen consumption rate. The daily net production rate was calculated from the daily gross production rate and the daily respiration rate.

There were several ponds in each purification plant. Each pond had different run time of filtration days. When the activities of all the ponds were measured, the values of different filtering days could be obtained.

Results and Conclusions

The daily gross production rates and respiration rates of the three plants are shown in Fig.1. The gross production rates were approximately the same rate in the three systems. However, it was clear that the lowest daily respiration rate was observed at the Sodeyama purification plant. In this plant, as much of the floating algae as possible was removed using a gill net. In the other two plants, part of the floating algae was drained through scum outlets.

The daily net production rates of the three plants are shown in Fig.2. In the Wakata and the Ishigaki purification plants, because daily gross production rates were approximately equal to daily respiration rates in value, daily net production rates were about $0g \cdot m^{-2} \cdot day^{-1}$. In the Sodeyama purification plant, because daily respiration rates were lower than daily gross production rates, daily net production rates showed a remarkably high positive value.

The floating algae were effectively removed from the SSF pond, with the results that the oxygen consumption rates became a small value, and oxygen production rates were the same value. Consequently, the removal of floating algae avoids oxygen depression, even in the nighttime. Thus it is effective in making desirable water.

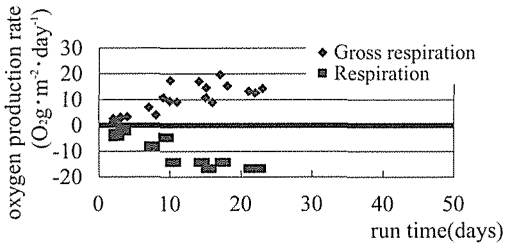

Fig. 1-1 Daily Gross production and Respiration at the Wakata plant

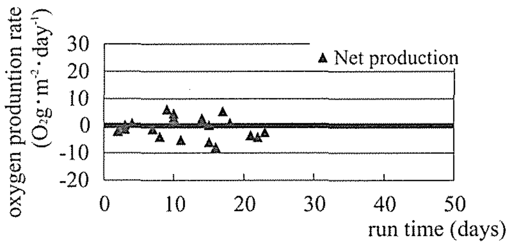

Fig. 2-1 Daily Net production at the Wakata plant

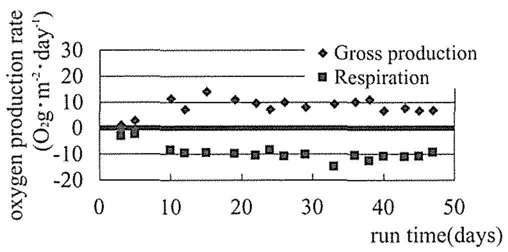

Fig. 1-2 Daily Gross production and Respiration at the Ishigaki plant

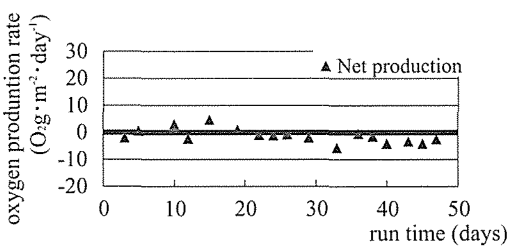

Fig. 2-2 Daily Net production at the Ishigaki plant

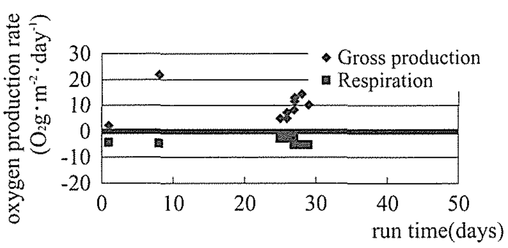

Fig. 1-3 Daily Gross production and Respiration at the Sodeyama plant

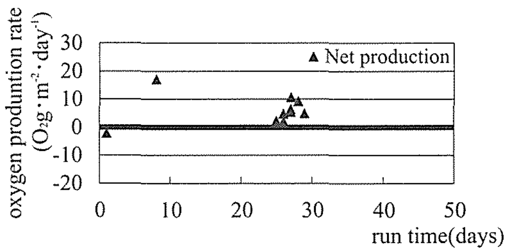

Fig. 2-3 Daily Net production at the Sodeyama plant

Improvements to the experiment

This study was carried out at real purification plants under different conditions. To obtain more reliable results, it is necessary to compare the phenomena under similar plant conditions. It is difficult to give a further treatment for the floating algae to the real plant. Thus, it is necessary to create a model experiment of SSF.

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