

メソコズムにおける渦鞭毛藻 *Peridinium bipes* による ブルームの紫外線抑制

Suppression of dinoflagellate *Peridinium bipes* bloom in a mesocosm by ultraviolet radiation.

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論文要約

メソコズムを用いて渦鞭毛藻 *Peridinium bipes* によるブルームに対する紫外線の抑制効果を調べた。長さ5m、幅5m、深さ4mの水槽にダム湖の *P. bipes* のブルームを閉じ込めメソコズムを作製し、ダム湖に設置した。このメソコズムの中央部水中に波長235.7nm、出力30W、長さ123cmの紫外線灯をつけた。2日後にはほとんど全ての *P. bipes* は消滅し、4日後には透明度が2.9mから4.5m以上に上昇した。実験期間中、アンモニア態窒素の濃度は増加したが、オルトリン酸や硝酸態窒素などの藻類の増殖に関わる他の栄養塩濃度の変化は見られなかった。このことから、紫外線照射は、*P. bipes* のブルームの抑制にたいして有効な方法であると考えられた。さらにメソコズム実験を基に、現場における *P. bipes* のブルームの抑制に必要な紫外線灯の数と必要日数の試算を行った。

Abstract

Suppression of dinoflagellate *Peridinium bipes* bloom by ultraviolet (UV) radiation was surveyed in a mesocosm. The mesocosm was 5m long, 5m wide, 4m deep, and contained a UV lamp 123cm long with a output power of 30W emitting 253.7nm light. The mesocosm was placed in a reservoir. Almost all live cells were eliminated from the water within 2days. Transparency increased from 2.9m to higher than 4.5m

in 4 days. Although ammonium nitrogen increased, no notable changes were observed in the concentrations of the important nutrients for algal growth such as orthophosphate and nitrate nitrogen. Therefore UV radiation was taken to be an effective way of suppression of *P. bipes* bloom. According to the results obtained from the mesocosm experiment, the number of UV lamps and the days required for killing all the cells in a reservoir were estimated.

Introduction

The dinoflagellate *Peridinium bipes* often causes blooms in reservoirs (Watanabe et al., 1983; Kubo et al., 1988; Watanabe et al., 1990). The bloom causes deterioration in scenic value and degrades water quality, sometimes causing serious odor problems. Therefore, it is of importance for water quality management to suppress the bloom. Many strategies for mitigating eutrophication of lakes and reservoirs have been developed (Uhlmann, 1982; The Ministry of Construction, 1988; Kojima, 1988). There is yet, however, no effective method for suppression of *Peridinium* blooms because these organisms grow in less eutrophicated water.

The effect of ultraviolet (UV) radiation on the survival of *P. bipes* was surveyed in the laboratory (Kawabata et al., 1990). This suggested the possibility of applying UV radiation for

the suppression of an increase in population density or for elimination of the *P. bipes* bloom in reservoirs. In order to evaluate the applicability of UV radiation in reservoirs, it is necessary to conduct experiments in as large systems as possible. The purpose of this study was to elucidate the effect of UV radiation on the survival of *P. bipes* and on the water quality in the mesocosm which was placed in the reservoir.

Materials and methods

A mesocosm was installed in a reservoir in Miyazaki Pref., Japan in late October, 1989, by enclosing the surface water column (75.2m³) containing *P. bipes* bloom. The mesocosm, made of waterproof canvas, was 4m long, 4m wide, 5m deep. In the mesocosm, an UV lamp (GL90SH, Sankyo Denki Co., Ltd. Japan), 123cm long with a output power of 30W emitting 253.7nm light, was fixed vertically under the water surface. Aeration was conducted at the lower end of the UV lamp at 5 liters per minute (Fig.1). The culture was allowed to grow under the continuous UV radiation for 5days. A control experiment was carried out in the mesocosm without a UV lamp.

Samples were taken at 7 points at each depth -0.1m, 2m and 4.5m -with a one-liter Heyroht water sampler. The seven samples were mixed at a certain depth and used for counting the cells and for chemical analyses. Values were expressed by mean values per mesocosm. They were calculated by the summation of the value at 0.1m depth multiplied by 0.2, at 2m depth by 0.4, and at 4m depth by 0.2. One ml of the sample was transferred into a 1mm deep, 20×50mm counting chamber marked off into 1mm squares. All the moving cells, non-moving cells and dead cells were counted under a phased microscope. Counting, which was repeated 5 times in this way using the same sample, gave 2.5% of a coefficient deviation of $s/x \times 100$ (s:standard deviation of the sample, x : mean value of the sample). Discrimination of dead cells from non-moving cells was done according to apparently destroyed cytoplasm.

Determinations of turbidity (Tur.), chemical oxygen demand (COD), total nitrogen (TN), ammonium nitrogen (NH₄-N), nitrite nitrogen (NO₂-N), nitrate nitrogen (NO₃-N), inorganic orthophosphate (PO₄-P), and total phosphorus (TP) were made according to JWVA (1985). Determinations of chlorophyll a (Chl a) and odor intensity (OI) were made according JIS Committee (1986). Transparency (T) was measured by a Secchi disk with a diameter of 25cm. pH was done with pH meter with a glass electrode (Horiba F-15). Water temperature (WT) and dissolved oxygen (DO) were measured vertically in the mesocosm using a thermistor (YSI Model 33 S-C-T Meter)

and DO meter (YSI Model 58), respectively. Water current was measured by a current meter (Model TK101D, Tohokeisoku Co., Ltd. Japan). The intensity of UV radiation was measured by a radiometer (Model UVX Digital Radiometer, UVP Inc., USA).

Results and discussion

Intensity of UV in the mesocosm decreased proportionally with distance (Fig. 2). This indicates that vertically proportional attenuation in UV intensity would be observed when the UV lamp is installed horizontally. Water circulated within 10 to 20 minutes, going down along the wall of the mesocosm, going up along the UV lamp and spreading out on the surface away from the UV lamp (Fig. 3).

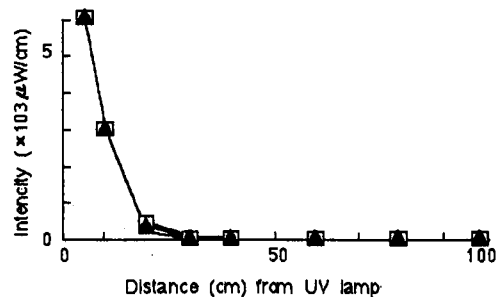


Fig. 2. Intensity of UV at each distance from the UV lamp at each depth (●; 20cm, ○; 40cm, △; 60 cm, □; 80cm).

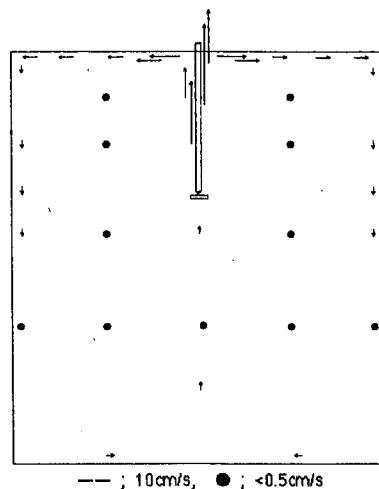


Fig. 3. Distribution of water current in the aerated mesocosm.

In the experiment without UV radiation which was carried out prior to the UV radiation experiment, no noticeable changes in water quality and the number of *P. bipes* were found. Therefore, results obtained at the mesocosm with UV radiation are shown here. The bloom of *P. bipes* in the mesocosm disappeared because of water circulation when aeration began. Changes in the numbers of moving, non-moving and dead cells are shown in Fig. 4. Almost all live

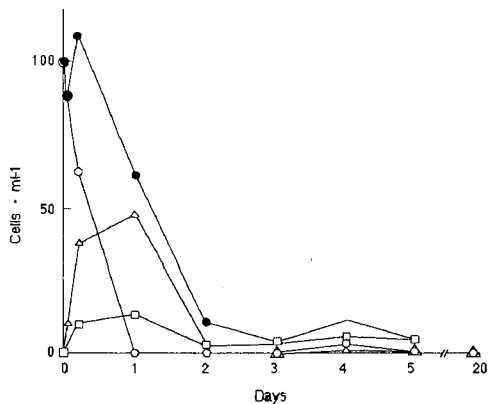


Fig. 4. Changes in the number of cells (total ; ● , moving ; ○ , non-moving ; △ , and dead □).

cells were eliminated from the water within 2days. No moving cells were observed during 15 the days after the experiment in the mesocosm which was left without UV radiation. The UV radiation in this size of mesocosm was as effective as $80 \mu w \text{ cm}^{-2}$ of UV radiation on a petri dish in the laboratory (Kawabata et al., 1990). *Peridinium* migrates downward at night (e. g. Berman & Rodhe, 1971; Sibley et al., 1974). This was also observed for *P. bipes* (Watanabe et al., 1983). As UV attracts *P. bipes* (Iseri & Kawabata, unpubl.), UV radiation at night doesn't seem to have a reduced effect on the suppression of *P. bipes*.

Changes in water quality before and on the fourth day of UV radiation are shown in Table 1. Transparency apparently increased. Factors affecting transparency such as Tur and Chl a decreased. Although $\text{NH}_4\text{-N}$ increased, no notable changes were observed in the concentrations of the important nutrients for algal growth such as $\text{PO}_4\text{-P}$ and $\text{NO}_3\text{-N}$. It doesn't seem that an immediate increase in the concentration of $\text{NH}_4\text{-N}$ induces algal growth after UV treatment because available phosphate is limited for phytoplankton growth.

Table 1. Changes in water quality before and on the fourth day of UV radiation

	WT °C	DO %	pH	T m	Tur. degree	OD mg/l	TN g/l	$\text{NH}_4\text{-N}$ ug/l
Before	16.2	96	7.5	2.9	1.2	2.4	509	31
On the 4th day	16.1	102	7.4	>4.5	0.5	2.2	680	275

	$\text{NO}_3\text{-N} + \text{NO}_2\text{-N}$ ug/l	TN ug/l	$\text{PO}_4\text{-P}$ ug/l	TP ug/l	Chl a ug/l	OI
Before	8	470	3	11	81	2
On the 4th day	11	394	0	15	62	1

Judging from the survival of *P. bipes* and the water quality, UV radiation was taken to be an effective way of suppression of *P. bipes* bloom. In the reservoir where this experiment was carried out, the bloom of *P. bipes* is usually observed in the upper area of $4.2 \times 10^4 \text{ m}^2$. Assuming that UV radiation using a UV lamp is enough to kill all live cells in $4 \times 4 \text{ m}^2$ for 2days and that the UV lamp is moved to adjacent areas after this treatment, it was estimated that a continuous UV radiation for 28 days using 200 UV lamps is required to suppress the bloom. According to Kawabata et al. (1990), UV radiation stronger than $2400 \mu W \text{ cm}^{-2}$ for one minute is enough to eventually kill all the cells. In this case, it was estimated that 2days were required for eliminating all the cells. It is necessary to conduct an experiment using a pilot plant *in situ* to evaluate with more accuracy the effect of the UV radiation on the suppression of the bloom *in situ*.

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