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EFFECT OF SHAPE OF SEDIMENT TRAP ON MEASUREMENT OF VERTICAL FLUX OF PARTICLES: PRELIMINARY RESULTS

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Abstract: Settling experiments were conducted to study sinking characteristics of phytoplankton cells within sediment traps. Simulated traps with three different shapes, *i.e.* cylindrical and conical shape with 75 and 60 degree angles, were employed for laboratory experiments. *Navicula* sp. as non-motile species and *Tetraselmis* sp. as motile one were employed for the experiment. Vertical flux of phytoplankton cells was determined continuously with a fluorometer. The present study indicated that conical shape traps caused underestimation of flux and the degree of underestimation was a function of wall angles. The underestimation was accelerated for *Tetraselmis* sp. The present results may suggest that a deployment of conical shape traps with collectors at the bottom would seriously underestimate the vertical flux of particles in the ocean.

1. Introduction

Sediment traps are one of the most common tools in oceanography (SOUTAR *et al.*, 1977) and the most effective tools in the ice-covered oceans (FUKUCHI *et al.*, 1989; BATHMANN *et al.*, 1991). Since sediment traps have been widely employed in the ocean, many problems have been recognized. Firstly the hydrodynamic effect on particles around a trap's mouth may cause a serious underestimation of vertical flux when a current speed is faster than 30 $cm \cdot s^{-1}$ (BAKER *et al.*, 1988). To reduce this effect baffles have been placed at the mouth of sediment traps (GARDNER, 1980a, b). However more important aspect of deployment of traps is a problem of tilting caused by strong current (GARDNER, 1985). Tilting a cylindrical trap either upstream or downstream will increase its collection rate at tilt up to 45°. Secondly, the effect of shape of trap, particularly an aspect ratio which is a ratio of height to mouth diameter is significantly important to determine the trapping efficiency of particles (GARDNER, 1980a, b, 1985; HONJO *et al.*, 1992). Thirdly, the effect of swimmers can modify the trapped sediment (PETERSON and DAM, 1990). In addition to the previously recognized occurrence of zooplankton, cryptic zooplankton which are not easily distinguished from the detrital material can also significantly modify the sedimentation of particles (MICHAELS *et al.*, 1990). Live organisms on particles also modify the sedimentation flux of particles when they attach to particles within a trap (SILVER and GOWING, 1991). To increase the collection of particles a large opening of funnel with small collectors at the bottom is widely used when a large amount of sedimented material is required (HONJO *et al.*, 1992). However a conical shaped trap can underestimate a vertical flux (LAWS *et al.*, 1989). In the present study the effect of slope of wall on a settling velocity was determined with three different slopes of wall in a laboratory. Fluorescence technique (EPPLEY *et al.*, 1976) was employed to study sinking behavior of particles within a trap.

2. Materials and Methods

To simulate a sediment trap, specially designed cylindrical tubes were made (Fig. 1). An inner diameter and a height of settling tubes were 25 mm and 1 m, respectively. The settling tubes were covered with a black tape with a transparent window (3 cm height) at the bottom of tube. Cone with two different angles was placed above the window. One settling tube without cone was prepared. The settling tube was filled with f/2 strength of the "f" culture medium (GUILLARD and RYTHER, 1955) before the experiment. A space with 12 mm depth was left for inoculation. The settling tubes were fitted to a Turner Designs fluorometer Model 10 with a Rika-Denki Model GP-1B chart recorder. The fluorometer read the accumulation of particles at the bottom of settling tubes. The settling tube was kept in this position at 20°C for longer than 24 hr to stabilize the column prior to the experiment.

The experimental species in the present study were green alga *Tetraselmis* sp. and diatom *Navicula* sp. They were grown in f/2 medium. The inocula obtained from the culture which had been growing at the log-phase were provided for the settling experiment. The inoculum was diluted with distilled water by 20% by volume to make the density lower. This procedure did not change any sinking behavior of cells of both species. Identical settling velocity was obtained with non-diluted and diluted inocula. The inoculum (5 m*l*) was introduced into a settling tube through a funnel with a small opening to reduce any disturbance caused by the inoculation. After the inoculation the top of settling tube was covered with a black plastic to eliminate any effects by ambient light for a fluorometric measurement. Cell density and chlorophyll *a* content of inocula were determined at each experiment. The cell numbers were counted on a hematocytometer. The concentration of chlorophyll *a* was determined on Turner Designs Model 10 fluorometer with a method described by HOLM-HANSEN *et al.* (1965).

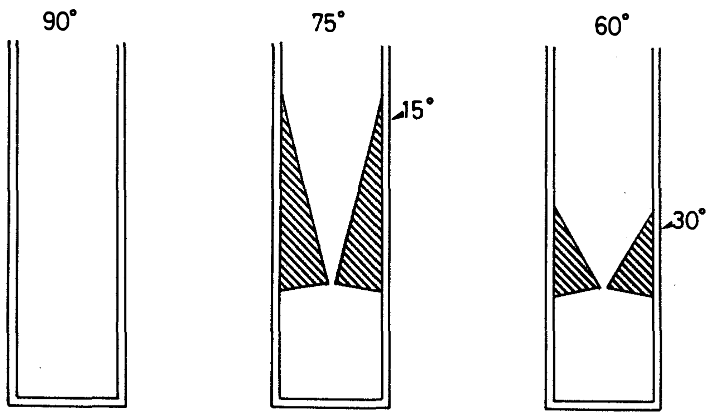

Fig. 1. Vertical section of settling tubes with and without cone. The values above each tube indicate the angle of cone-wall from the vertical wall. Bottom diameter of cone is 3 mm.

3. Results

One of the typical results is shown in Fig. 2. There were three phases on settling. Firstly, a background level of fluorescence was seen. Secondly, a steady increase of fluorescence was observed. The slope of fluorescence curve was proportional to a settling velocity of particles. Finally, a plateau of fluorescence was reached when a supply of particles was exhausted. These three phases were always observed for both species with experimental cell density and chlorophyll *a* content (Table 1). The initial slope of fluorescence curve and the half saturation constant were calculated for three shapes of settling tubes with two species (Table 2). The steepest slope was always obtained from the experiment without cone for both species. Half-saturation constant was also the smallest in the experiment without cone for both species. At the given condition in the present study a degree of underestimation of the initial slope for the angle of 75° was 8% for *Navicula* sp. and 15% for *Tetraselmis* sp., respectively. This trend was enhanced significantly for the angle of 60° to 17% for *Navicula* sp. and 68% for *Tetraselmis* sp., respectively.

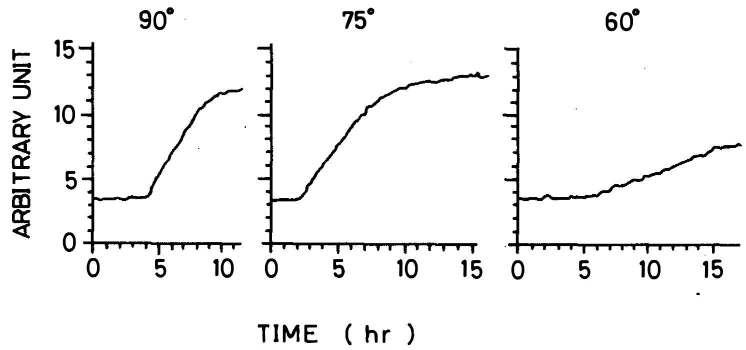

Fig. 2. Typical curves of in vivo *fluorescence for three settling tubes obtained with* Tetraselmis *sp.*

Table 1. Cell density and chlorophyll a *content of inocula cultured.*

Species	*Navicula* sp.	*Tetraselmis* sp.
Cell density (10^6 cells ml^{-1})	120±48	110±28
Chlorophyll *a* (mg m^{-3})	200±41	120±34

Table 2. Initial slope and half-saturation time of settling velocity determined with each collector's angle for Navicula *sp. and* Tetraselmis *sp.*

Species	*Navicula* sp.			*Tetraselmis* sp.		
Angle (degree)	90°	75°	60°	90°	75°	60°
Slope (degree)	65°	60°	54°	65°	55°	21°
Half-saturation (hour)	1.4	2.4	4.6	2.4	3.5	4.8

4. Discussion

Since settling behavior of particles within a trap depends on light intensity and on nutrient status and physiological stage of the cells (BIENFANG *et al.*, 1982, 1983; CULVER and SMITH, 1989), the present experiments were carried out in a dark condition with enriched filtered seawater and inocula from the culture in the log-phase of growth. Settling does not occur evenly on the bottom of cylindrical trap (ASPER, 1987). Wall of cone modifies sinking behavior of most particles. There are several possible reasons for this modification. Shape of particles such as single round cell or chain-forming cells is one of the important factors to control a sinking behavior (SMAYDA, 1971). Too many particles compared to a size of bottom of cone can force all particles traveling at reduced sinking velocity particularly in the highly productive ocean. Surface charge produced by cells causes variability in sinking velocity (HUNTER and LISS, 1982). Surface properties such as extracellular products released by cells produce adhesive surface which changes viscosity of cells (IGNATIADES and FOGG, 1973; ALLDREDGE and SILVER, 1988).

The present results were a product of all combined factors mentioned above. Difference in degree of wall effect between two species can be due to their motile characteristics. Stronger effects on the slope found in *Tetraselmis* sp. may be due to the cells with four flagella. Once the cells touched the angled wall, the cells may be stimulated to swim upward. Consequently the sinking velocity is reduced significantly compared with *Navicula* sp.

Based on the present study, free-drifting sediment traps (STARESINIC *et al.*, 1982) with a cylindrical shape would be recommended for the biological study. In the polar seas ice algae are ecologically important component of ecosystem. They are often pennate diatoms such as *Navicula* and *Nitzschia* species (POULIN, 1990), which have the physiological ability to colonize in the ice. When ice algae are released from the ice, they tend to coagulate to form large aggregates (RIEBESELL *et al.*, 1991). Sedimentation characteristics of these large aggregates can not be identical between outside and inside of cone-shaped traps, causing a biased estimation of vertical flux. Cone-shaped traps should be used for a specific purpose with precaution.

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