Wat. Sci. Tech. Vol. 27, No. 11, pp. 231–240, 1993.

0273–1223/93 $24·00

SETTLING AND COAGULATION OF SLENDER TYPE DIATOMS

H. Konno

Department of Civil Engineering, Tohoku Institute of Technology, 35-1 Yagiyama Kasumicho Taikaku-ku Sendai 982, Japan

ABSTRACT

A slender type diatom is observed. The settling behavior and surface electrostatic situation of the diatom are discussed through the consideration of physiological activity and observation by SEM. By considering the settling behavior, one side of slender type diatoms such as *Nitzschia* and *Synedra* is heavier than the other side. The settling velocity is related to physiological condition of algae, for example the settling velocity in the endogeny phase is faster than it is in the logarithmic growth phase. The surface charging of diatoms is increased (more negative) by the existence of mucous algal borne substances at the surface of diatoms. It influences the neutralization. Aluminium hydroxide adsorbs at some specified points on the surface of diatoms, then the area covered aluminium hydroxide is spread. It is related to floc formation ability of the diatoms by bridging action.

KEYWORDS

Settling; Coagulation; Flocculation; Diatom, *Nitzschia*, *Synedra*; Physiological activity; Zeta potential; SEM

INTRODUCTION

Many problems in water supply are caused by various kinds of algae in eutrophicated water sources. There are problems of taste and odor, toxicity, obstruction to coagulation and sand filter clogging. One source of influence arises in water supply in some water treatment processes and another one is in the network of pipes and taps. Each influence is a serious and difficult problem.

The influence in the water treatment processes is concerned with general water treatment systems such as coagulation, sedimentation and filtration. Rapid sand filtration system is not suitable to remove the algae, as it has been developed for treatment of high density inorganic substances. Because the density of algae is low (Reynolds, 1975), algogenic substances cause obstruction to cogulation for general inorganic matter such as clay (Bernhardt, 1982; Magara *et al.*, 1986) and the characteristics of algae on the condition for coagulation is not stable though the size of algae is larger than colloidal matters.

In this report a slender type diatom which is well known as an algae causing filter clogging in rapid sand filtration systems is observed. Settling behavior and the character of coagulation for the diatoms are not clear. For the obstruction to coagulation, the influences after dissolving the algogenic substances to the water have been discussed. The influence on the settling and coagulation of diatoms caused by algogenic substances on the surface of diatoms should be also discussed. The settling behavior and surface electrostatic situation of diatoms are discussed with consideration of physiological activity and the observation by scanning electric microscope (SEM) in this report.

SETTLING OF SLENDER TYPE DIATOMS

Behavior of settling and the difference in the kinds of diatom

The kinds of algae considered are *Nitzschia linearis* and *Synedra acus* which are slender type diatoms. These diatoms are cultivated separately for experiment. The settling velocity of each diatom is measured by microscope in the still flow water tank. The diatoms are dispersed in a small water tank in a large water tank which is kept at constant temperature. The slender type diatoms settled to the downstream vertically. The settling velocity is the transit velocity in the depth between two lines, which is measured beforehand in the view of microscope. The profiles of one hundred settling velocities are shown in Fig. 1.

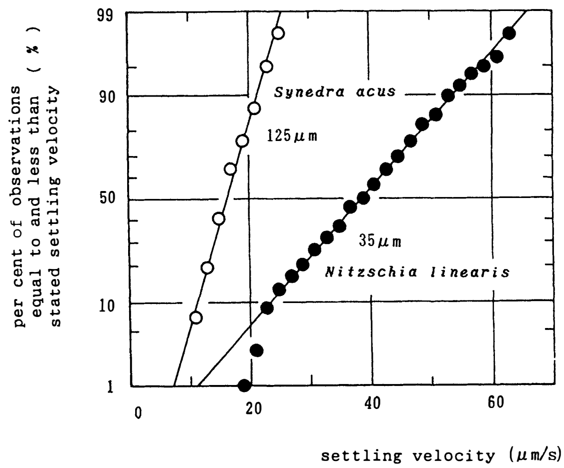

Fig. 1. Settling velocity profiles of slender type diatoms

The median settling velocity of *Nitzschia* of 35μm size in Fig. 1 is about 40μm/s (3.5m/d), that of *Synedra* 125μm is about 17μm/s (1.5m/d). The longer diatom *Synedra*, 3.6 times the size, has a slow settling velocity, 1/2.3 times. It is well known that *Synedra* causes sand filter clogging because of large size even if a small number of *Synedra* are carried over to the rapid sand filter. The efficiency of sedimentation for *Synedra* is low because the settling velocity is slow, and it is one of the reasons for the filter clogging. Generally, the settling velocity is related to the resistance coefficient of particles, relative density of the particles, the particle volume and the sectional area of the right angle crossing of the particles. The reasons slow settling velocity *Synedra* are that of the density of *Synedra* is lower than one of *Nitzschia* and the resistance coefficients of *Synedra* are larger.

Difference in physiological activity

The settling velocity of *Nitzschia* under the physiological conditions during the cultivation is measured by a similar method. The cultivation term is divided into three phases, logarithmic growth, stationary phase and endogeny phase. The velocity profiles in each phase are shown in Fig. 2.

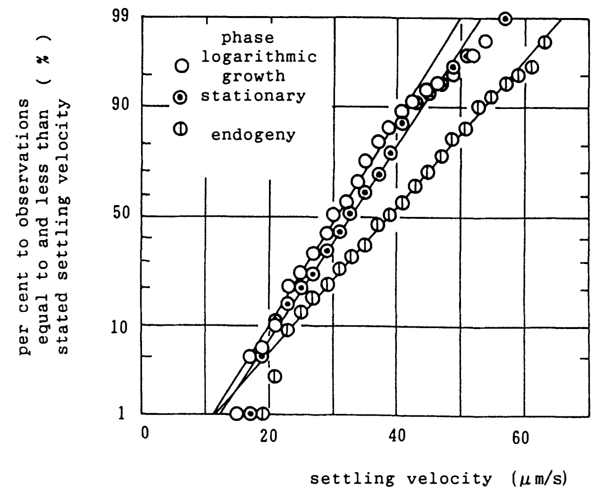

Fig. 2. Settling velocity profiles in each phase

The settling velocity of *Nitzschia* varies greatly depending on the physiological activity. The settling velocity of *Nitzschia* in the stationary phase is faster than in the logarithmic growth phase and the settling velocity gets faster at the endogeny phase. Generally speaking, microorganisms are easy to coagulate under the poor nutrient conditions. It is clear that the settling velocity of the diatoms in the stationary and endogeny phases becomes fast even for a non-coagulated diatom. It is considered that mucopolysaccharide volume at the surface of a diatom cell influences stream resistance. In endogeny phase, the production rate of the mucopolysaccharide of the declining diatom after physiological activity goes down the stream resistance gets smaller; as a result, the settling velocity gets faster. This is the reason for the improvement of the sedimentation efficiency of algae by the prechlorination process.

The settling velocity of the model slender type diatom having 0.064mm in diameter and 3 to 12mm in length with density, 1.40g/cm^3 is measured by a similar method. In the results, almost all model diatoms settled in a horizontal state. It is quite different with actual diatoms. It is indicated that one side of the actual slender diatom is heavier than the other side in any phase during cultivation.

COAGULATION OF SLENDER TYPE DIATOMS

Figure 3 shows the cultivation curve for *Nitzschia*. The diatom zeta potential in each phase is measured by a zeta meter. The coagulation condition of the jar test is that initial pH and alkalinity are adjusted at 7.0, 50 mg/l respectively, the number concentration of *Nitzschia* in raw water is also prepared at 2,000 cells/ml and coagulant is aluminium sulfate. Figure 4 shows zeta potential profiles of each diatom in raw water, settled floc and suspended floc. The relation between three median zeta potentials in the water and flocs and cultivation period is shown in Fig. 5. Figure 6 shows optimal dosage of the coagulant and the relation to cultivation period. All diatoms have a minus charge on the surface of them as well as clay suspensions. The average value (median value in profile) of zeta potential of diatoms in natural raw water is -30 to -35mV. After treating by coagulants such as aluminium salts the surface charge of diatoms is neutralized like the clay suspensions.

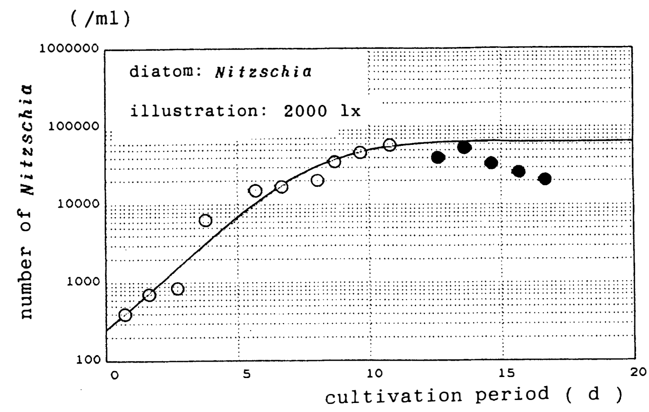

Fig. 3. Cultivation curve for *Nitzschia*

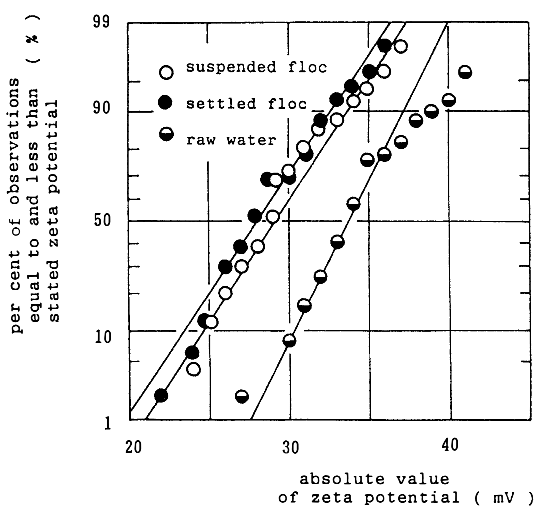

Fig. 4. Zeta potential profiles of diatoms

In Fig. 5, the median zeta potential and the profile of *Nitzschia* in the raw water are quite different according to its growth phase. At the initial growth phase the zeta potential is -30 mV, in the logarithmitic growth and near the stationary phase the zeta stage is -35 mV, after that in the stationary phase the absolute value of zeta potential becomes small even -28mV and it is -28 to -29 mV in the endogeny phase. It is indicated that in the stationary and endogeny phase the physiological activity of diatoms becomes weak through the absolute value of the zeta potential in the raw water is large in the logarithmic growth phase where the diatom is very active physiologically. The difference in the zeta potential due to the phase of proliferation is explained by assuming the existence of a large volume of alogenic substances, which promote a minus charge of the diatom, at the diatom surface in growth phase having high physiological activity.

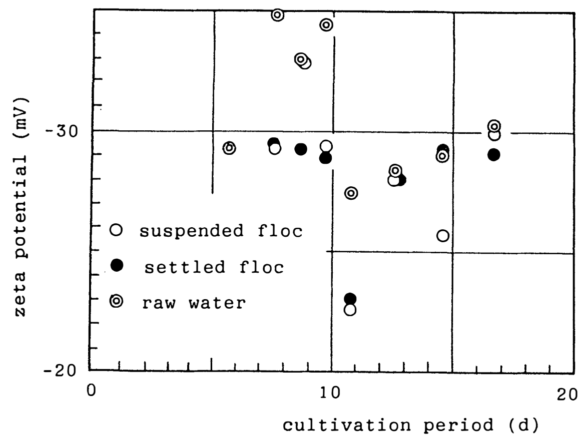

Fig. 5. Relation between median values of zeta potentials and cultivation period

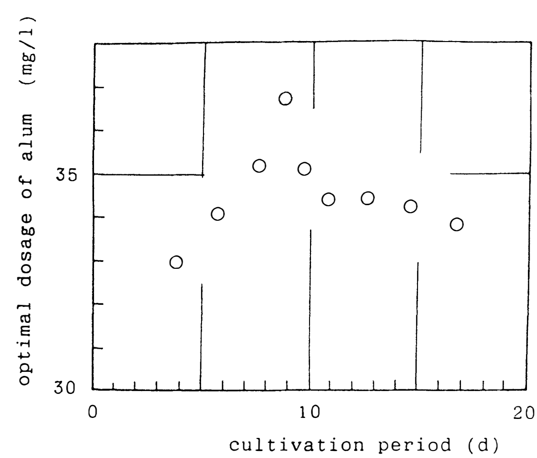

Fig. 6. Relation between optimal dosage in jar test and cultivation period

By Fig. 4, it is clear that the absolute value of the zeta potential of the diatom in the settled and suspended floc is 5 to 6mV smaller compared with raw water. It is explained as the result of the charge neutralization on the surface of diatom and the adhesion of aluminium hydroxide to the diatom. The extent of each function differs also in the growth phase as shown in Fig. 5. In the logarithmic growth phase with large minus charge, the efficiency of the neutralization of the surface of the diatom is high, on the other hand, the neutralization extent is low in the endogeny phase.

Considering an optimal dosage of coagulant in Fig. 6, it is increased with cultivation period to the stationary phase, but it is decreased conversely at the stationary phase and it becomes almost constant in the stationary and endogeny phase. In the growth phase, the coagulant dosage is increased because the zeta potential of the diatom is very negative. Regarding the surface charge potential and the neutralization of the charging, a schematic figure is shown in Fig. 7.

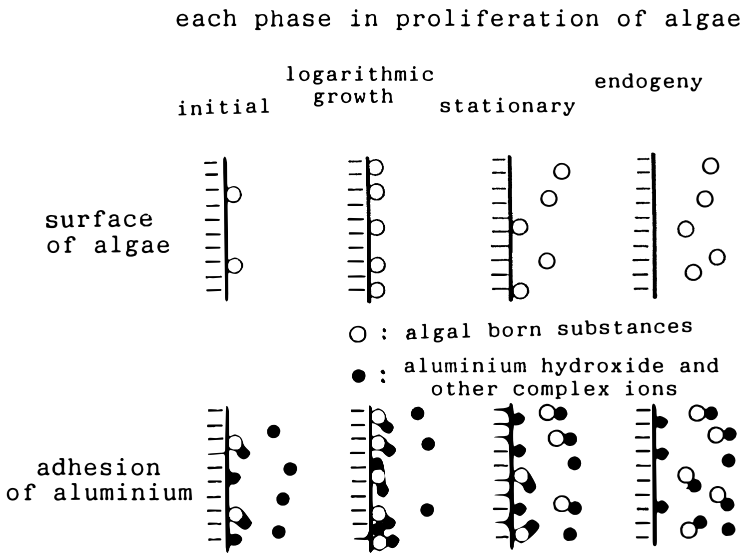

Fig. 7. Schematic diagram for surface charge and neutralization

The surface charging of algae is increased on the minus side by the existence of algogenic mucous substances at the surface of algae. In the logarithmic growth phase, the charge is the most negative because the product of the substances is increased. Then at the stationary and endogeny phases, the physiological activity become weak and the mucous substances at the surface of algae are worn off from the surface to water. By injecting the coagulants, some aluminium ions are adsorbed to the alga surface charged negatively and to the algogenic mucous substances, the neutralization of the charge is increased. If it is assumed that the ions are adsorbed more efficiently to the mucous substances compared with the algal surface, it is well understood that the efficiency of the neutralization is high in the logarithmic growth phase.

OBSERVATION OF THE SURFACE OF DIATOM BY SEM

Physiological activity and the surface of a diatom

The surface situation of *Nitzschia* at each proliferation phase and the floc formation in the settled and the suspended floc are absorbed by scanning electron microscope (SEM).

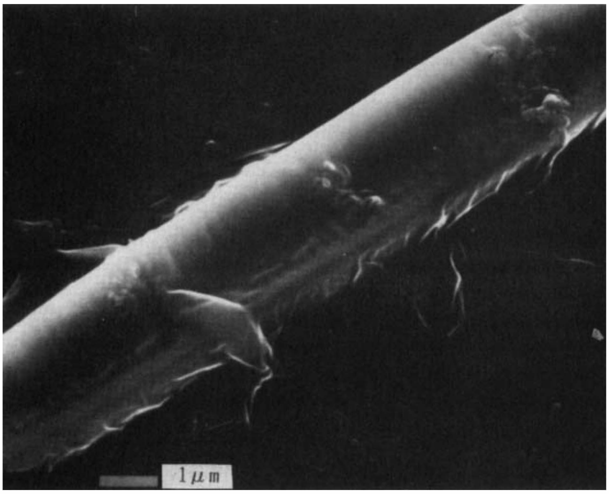

Fig. 8. Surface situation of *Nitzschia* at the logarithmic growth phase

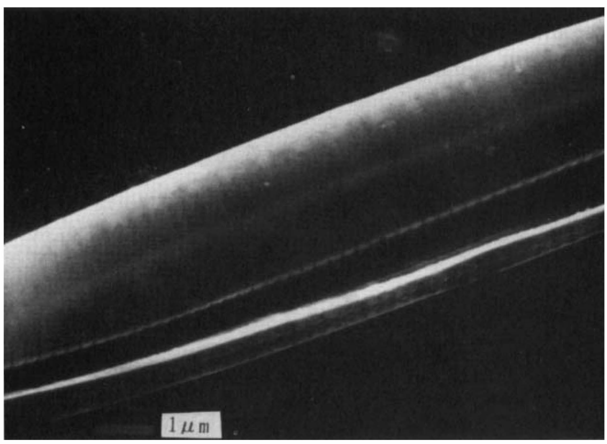

Fig. 9. Surface situation of *Nitzschia* at the endogeny phase

Figures 8 and 9 show the surface situations of *Nitzschia* at the logarithmic growth phase (cultivation period t = 8.7d) and at the endogeny phase (t = 16.7d), respectively. The special characteristics of the surface situation are that *Nitzschia* at the endogeny phase has a very smooth surface in comparason to the very rough surface in the growth phase in which the cell is dividing rapidly. It is considered that the difference in the surface situation causes the difference in the settling velocity. In fact settling velocity of *Nitzschia* in the endogeny phase is 30% higher than in the growth phase.

Floc formation and role of aluminium hydroxide

Figures 10 to 12 show the floc and the surface of *Nitzschia*, in the suspended floc at t = 16.7d, in the settled floc at t = 15.6d and the enlarged floc situation in the settled floc at t = 8.0d, respectively.

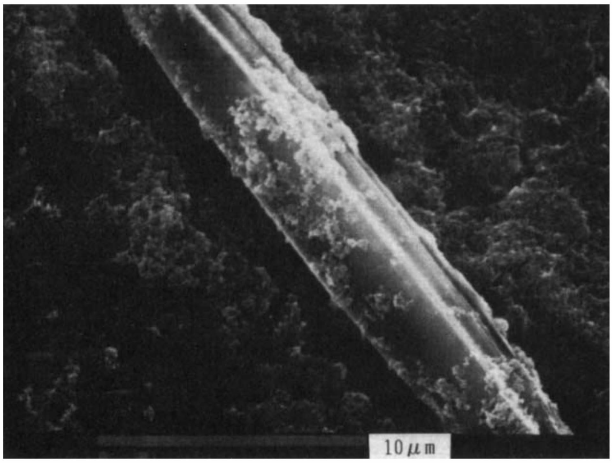

Fig. 10. Adhered materials on *Nitzschia* in the suspended floc

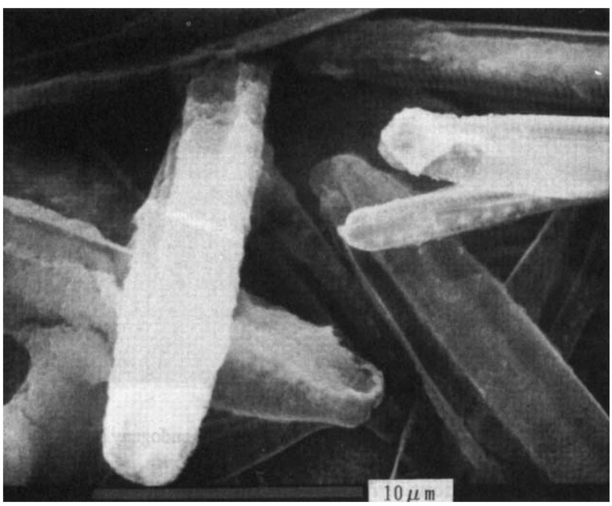

Fig. 11. The settled floc

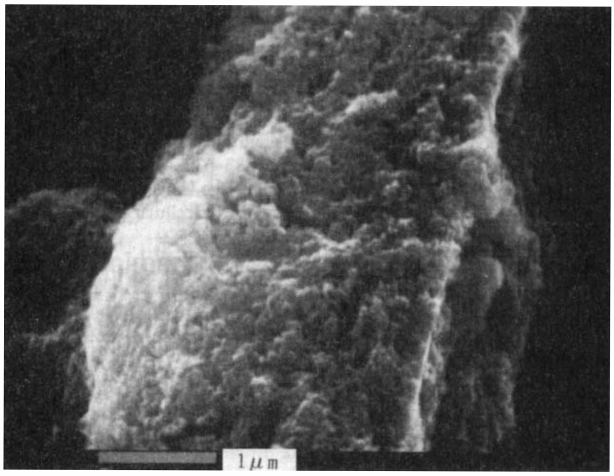

Fig. 12. Surface situation of settled floc

By studying the adhered materials in Figs 10 and 11, much adhered material is observed in the settled floc compared to the surface of *Nitzschia* in the raw water in Figs 8 and 9. It is considered that this material is aluminium hydroxide. By considering the situation of adhesion of aluminium hydroxide at the surface of the diatoms, it is hypothesized that formed aluminium hydroxide adhered the surface of diatoms firstly, then floc formation of diatoms is advanced under the bridging action of aluminium hydroxide on the surface of diatoms and as a result the settling velocity of floc is increased. The situation of floc formation is also understood from Fig. 12. For the adhesion of aluminium hydroxide to the diatoms, it should be considered that aluminium hydroxide firstly absorbs at some specified points on the surface of the diatoms, then the covering area of aluminium hydroxide on the surface is spread to the surface area of the diatoms. The thickness of the covering area of the aluminium hydroxide is not uniform around the surface.

CONCLUSIONS

A slender type diatom which is well known as algae causing filter clogging is studied. Settling behavior and the character of coagulation for the diatoms of discussed through the consideration of physiological activity and the observation by SEM in this report. In the result the following points are confirmed:

(1) The uniform (on weight) slender type model materials settle with horizontal state. But actual slender type diatoms settle downwards vertically. One side of slender type diatoms such as *Nitzschia linearis* and *Synedra acus* is heavier than the other side.

(2) It is well known that the densities of algae differ depending on the kind of algae. The settling velocity of diatoms is affected by the stream resistance to the surface roughness of diatoms at the rapid growth phase. The settling velocity of the diatoms in the endogeny phase is faster than that in the logarithmic growth phase because of smaller stream resistance the smooth surface of diatoms in the endogeny phase.

(3) The surface charge of diatoms is made more negative by the existence of mucous algogenic substances at the surface of diatoms in the growth phase. The tendency is remarkable at the logarithmic growth phase. The mucous substances are worn off from the surface by water at the stationary and the endogeny phase. In the case of neutralization, some aluminium ions are absorbed more efficiently to the mucous substances compared to the algal surface.

(4) Aluminium hydroxide firstly absorbs at some specified points on the surfaces of diatoms, then the covering area of aluminium hydroxide on the surface is spread to the surface area of the diatoms. Floc formation is advanced under the bridging action of adhered aluminium hydroxide on the surfaces of diatoms.

Floc formation ability of the diatoms covered with a small amount of aluminium hydroxide on the surface is weak.

REFERENCES

Bernhardt, H. (1982). Investigation of algogenic organic substances and their effect on water treatment. *Proc of the Japanese-German Workshop on Waste Water and Sludge Treatment*, pp. 583–637.

Reynolds, C. S. (1975). *The Ecology of Freshwater Phytoplankton*. Cambridge University Press.

Magara, Y., Kunikane, S. and Aizawa, T. (1986). The adverse effect of extracellular products of algae on coagulation process. *Journal of Japan Water Works Association*, **55** (4), 33–39.