La mer 28: 37-47, 1990
Société franco-japonaise d'océanographie, Tokyo

Seasonal changes of the Secchi disc depth and suspended solid at six stations along the main channel of the High Dam Lake, Egypt*

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Abstract: Seasonal changes of the Secchi disc depth, suspended solid, chlorophyll *a*, ignition loss and particulate organic matter were investigated at six stations (Stns. 1-6) along the main channel of the High Dam Lake in Egypt during the period from September 1986 to December 1988. Water samples were collected from the surface and 2 m layer at each station and analyzed. Patterns of seasonal changes of the parameters and the ratios of chlorophyll *a* to suspended solid and to particulate organic matter were similar mostly among Stns. 1-3 in the northern part and among Stns. 4-6 in the southern part of the lake. The Secchi disc depth was significantly correlated with suspended solid in a hyperbolic manner when the two parameters were plotted on linear scales. It is shown that both the ratios of chlorophyll *a* to suspended solid and to particulate organic matter are regionally and seasonally quite variable.

1. Introduction

The High Dam Lake is one of the largest artificial lakes in Africa. It was filled in 1960 after the construction of Aswan High Dam (ENTZ, 1974). In order to know the environmental conditions of the High Dam Lake, the Fishery Management Center (FMC) of the High Dam Lake Development Authority, Egypt, set up stations in the main channel and in Khor El Ramla in 1982, and has been conducting monthly field surveys. The distributions of chlorophyll *a* in Khor El Ramla and adjacent water in the main channel were partly reported in a previous paper (OLFAT *et al.*, 1987). The results obtained in the main channel were reported by OLFAT and ARUGA (1988). In these reports the relationships between chlorophyll *a* and Secchi disc depth were presented with rather scattered data, suggesting that the proportion of chlorophyll *a* in suspended solid might be variable presumably according to the seasons and regions of the lake.

The present paper describes the seasonal changes of the Secchi disc depth and suspended solid at six stations along the main channel of the High Dam Lake in relation to chlorophyll *a* concentration and ignition loss, mainly focusing on the relationship between the Secchi disc depth and the suspended solid.

2. Material and methods

Water samples were collected from the surface and 2 m depth with a Van Dorn type water sampler at six stations (Stns. 1-6) from September 1986 to December 1988 (Fig. 1). Each water sample was filtered through a glass fiber filter (Whatman GF/C, 47 mm) which was precombusted at 450℃ for 3 hrs in a Muffle furnace and weighed, and the filter with suspended solid on it was weighed after drying overnight (or for 24 hrs) in a drying oven at 85℃. The amount of suspended solid (SS) was determined as the difference of dry weights before and after filtration of water sample. The filter was ignited again in a Muffle furnance at 450℃ for 3 hrs and weighed after cooling, and the percent decrease of dry weight was regarded as the ignition loss

* Received October 15, 1989
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(IL). The amount of particulate organic matter (POM) was calculated by multiplying SS with IL.

The transparency of water was measured with a Secchi disc (30 cm in diameter) at each station. The chlorophyll *a* concentration was determined in the same way as described in previous papers (OLFAT *el al.*, 1987; OLFAT and ARUGA, 1988).

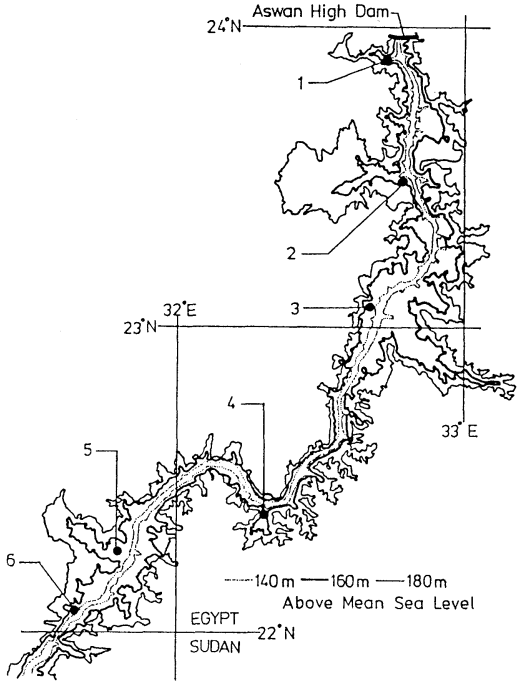

Fig. 1. Map of the High Dam Lake showing the locations of stations (1-6).

3. Results

The Secchi disc depth was highest, 5.7 m, in February 1987 at Stn. 4 and lowest, 0.2 m, in September 1988 at Stn. 6. Seasonal changes of the Secchi disc depth at Stns. 1-6 are illustrated in Fig. 2. In average, the Secchi disc depth was highest in February and lowest in August. It is noticeable that differences of the readings at six stations were small from April to June but large from August to March. Among the six stations, the Secchi disc depth was mostly lowest at Stn. 6, whereas at Stn. 1 it was highest except in January-March 1987 and February 1988. This suggests the decrease of suspended solid with flowing water along the main channel. Stns. 1 and 2 showed similar seasonal changes of the Secchi disc depth, and Stns. 5 and 6 also showed similar changes. Stn. 3 showed quite similar changes to the average of the six stations. Seasonal pattern at Stn. 4 was different from those at other stations in having big differences between the maximum and the minimum values.

Seasonal changes of the amount of suspended solid in the surface water and 2 m layer at Stns. 1-6 are illustrated in Fig. 3. The level of suspended solid was generally higher (1.0 - 59.0 g/m^3) at Stns. 4-6 in the southern part and lower (0.5 - 10.0 g/m^3) at Stns. 1-3 in the northern part of the lake. The patterns of seasonal changes of suspended solid were similar among Stns. 1-3 and among Stns. 4-6, but the patterns at the latter stations were

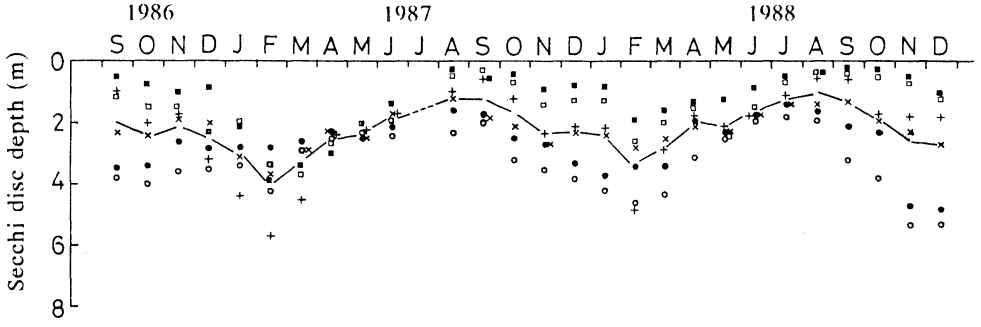

Fig. 2. Seasonal changes of the Secchi disc depth (Ds) at Stns.1-6 in the main channel of the High Dam Lake. The line is for averages of the six stations. ○, Stn.1; ●, Stn.2; ×, Stn.3; +, Stn. 4; □, Stn.5; ■, Stn.6.

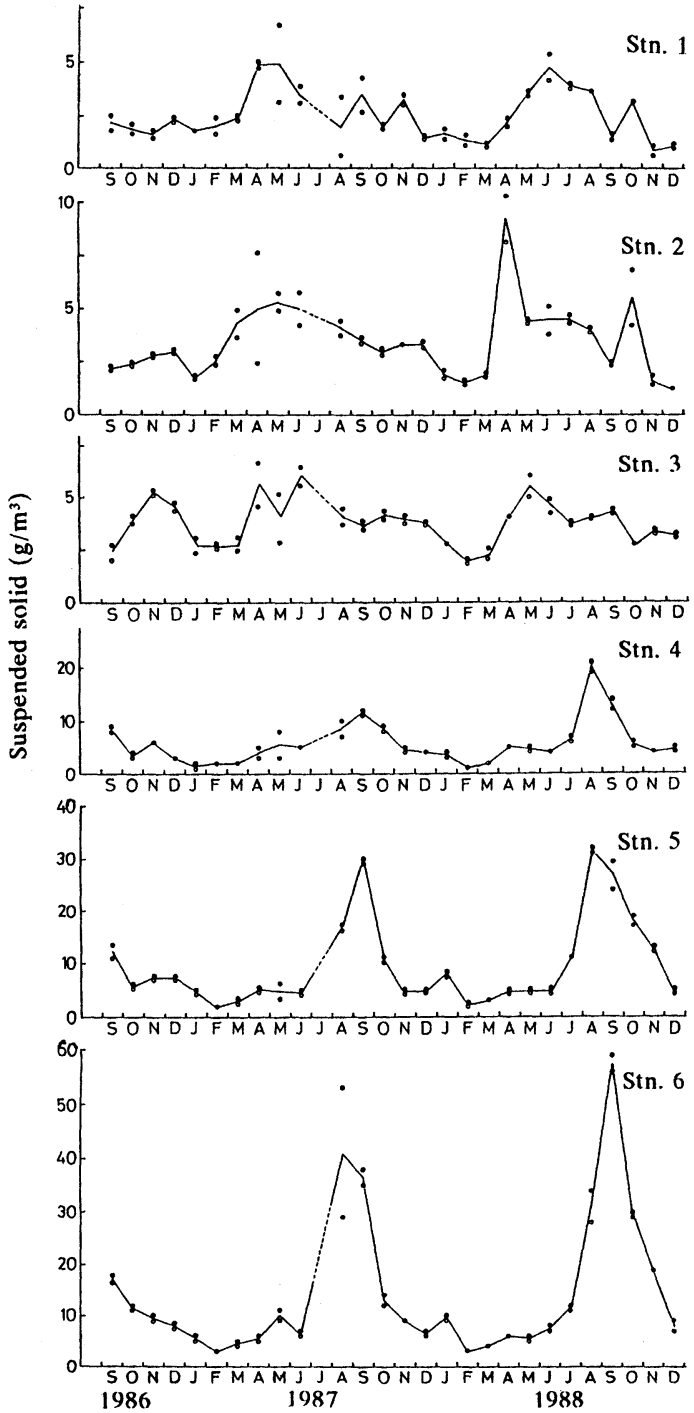

Fig. 3. Seasonal changes of the suspended solid at Stns. 1-6 in the main channel of the High Dam Lake. Lines are for averages of the surface (○) and 2 m (●) samples.

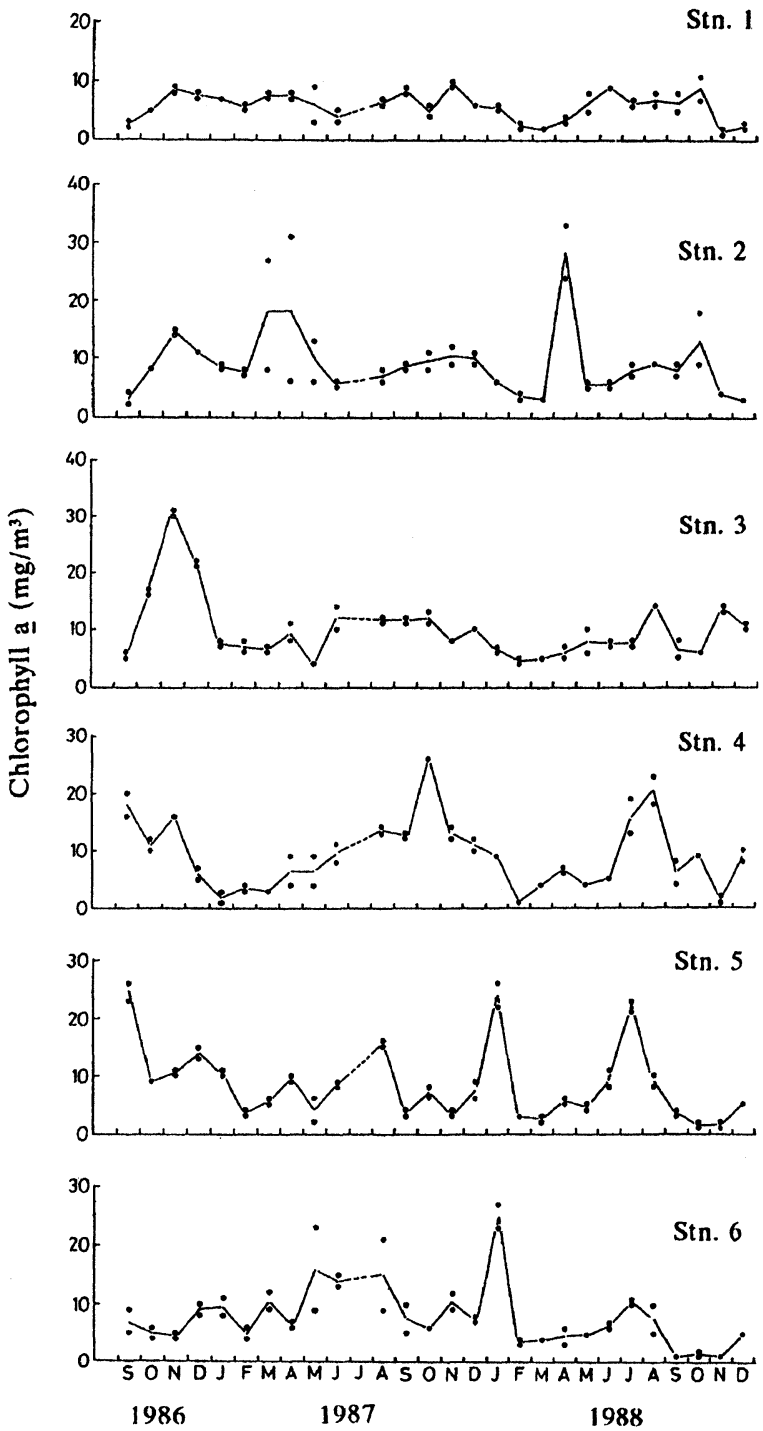

Fig. 4. Seasonal changes of the chlorophyll *a* at Stns.1-6 in the main channel of the High Dam Lake. Lines are for averages of the surface (○) and 2 m (●) samples.

clearly different from those at the former stations. The range of variations was quite big at Stns. 4-6 as compared with that at Stns. 1-3. Rapid increases in suspended solid were observed in April and May at Stns. 1-3 in 1987 and 1988, whereas at Stns. 4-6 rapid increases were observed in August and September in 1987 and 1988. The suspended solid was clearly high during the flood season (August-October) at Stns. 4-6.

Figure 4 illustrates seasonal changes of chlorophyll *a* concentration in the surface water and 2 m layer at Stns. 1-6. Average chlorophyll *a* concentrations were slightly higher at Stns. 4-6 (1-26 mg/m^3) than at Stns. 1-3 (1-21 mg/m^3), if the higher values of 28 mg/m^3 at Stn. 2 in April 1988 and 30 mg/m^3 at Stn. 3 in November 1986 were excluded. The seasonal patterns of chlorophyll *a* concentration were similar among Stns. 1-3 and among Stns. 4-6, even though the patterns at Stns. 1 and 6 were somewhat obscure as compared with those at other stations. The patterns at Stns. 1-3 were different from those at Stns. 4-6. The range of seasonal variations of chlorophyll *a* concentration was big at Stns. 4-6 as compared with that at Stns. 1-3. The patterns of seasonal changes of chlorophyll *a* concentration (Fig. 4) were different from those of the suspended solid (Fig. 3) at each station, even though the corresponding peaks were sometimes observed.

Figure 5 shows seasonal changes of the ignition loss of suspended solid in the surface water and 2 m layer at Stns. 1-6. The ignition loss was generally higher (25-98%) at Stns. 1-3 and lower (6-92%) at Stns. 4-6. The patterns of seasonal changes of ignition loss were similar among Stns. 1-3 and among Stns. 4-6. However, the patterns at the latter stations were clearly different from those at the former stations. The pattern at Stns. 4-6 were characterized by the lower levels of ignition loss mainly in 1988. Variations in ignition loss were big at Stns. 1-3 as compared with those at Stns. 4-6. Rapid increases in ignition loss were observed in August and September at Stns. 1-3 in 1987 and 1988, whereas at Stns. 4-6 rapid decreases were observed in the same period in 1987 and 1988. These differences could be due to the differences of variations in the proportion of inorganic suspended solid to the particulate organic matter or to the total suspended solid in the lake water. The patterns of seasonal changes of the ignition loss (Fig. 5) were quite different from those of the suspended solid (Fig. 3). This suggests that there had been big seasonal variations in the proportion of inorganic suspended solid to the total suspended solid or to the particulate organic matter.

Seasonal changes of the amount of particulate organic matter in the surface water and 2 m layer at Stns. 1-6 are illustrated in Fig. 6. The levels of particulate organic matter at Stns. 1 and 3 were comparatively low as compared with those at other stations. The average amount of particulate organic matter ranged from 0.4 to 7.5 g/m^3. Similar seasonal patterns were observed with the maximum in July-September and the minimum in December-February at Stns. 4-6. The seasonal patterns were similar at Stns. 1-3 if the two sharp peaks at Stn. 2 in April 1987 and 1988 were excluded. The range of variation was quite big at Stns. 4-6 as compared with that at Stns. 1-3. Peaks of particulate organic matter appeared a little earlier at Stns. 1-3 (April-July) than at Stns. 4-6 (July-August). The seasonal patterns of particulate organic matter (Fig. 6) were similar to those of suspended solid (Fig. 3) except that at Stn. 6.

Figure 7 shows seasonal variations of the percentage of chlorophyll *a* in suspended solid in the surface water and 2 m layer at Stns. 1-6. The average percentage of chlorophyll *a* was higher at Stns. 1-3 (0.1-0.6%) than at Stns. 4-6 (0.01-0.3%). The patterns of seasonal changes of the percent chlorophyll *a* in suspended solid were similar among Stns. 1-3 with higher values during November-January and lower values during May-July, and between Stns. 5 and 6 with higher values in January or February and lower values in September and October. The seasonal patterns at the former stations were clearly different from those at the latter stations. The patterns at Stns. 4-6 were characterized

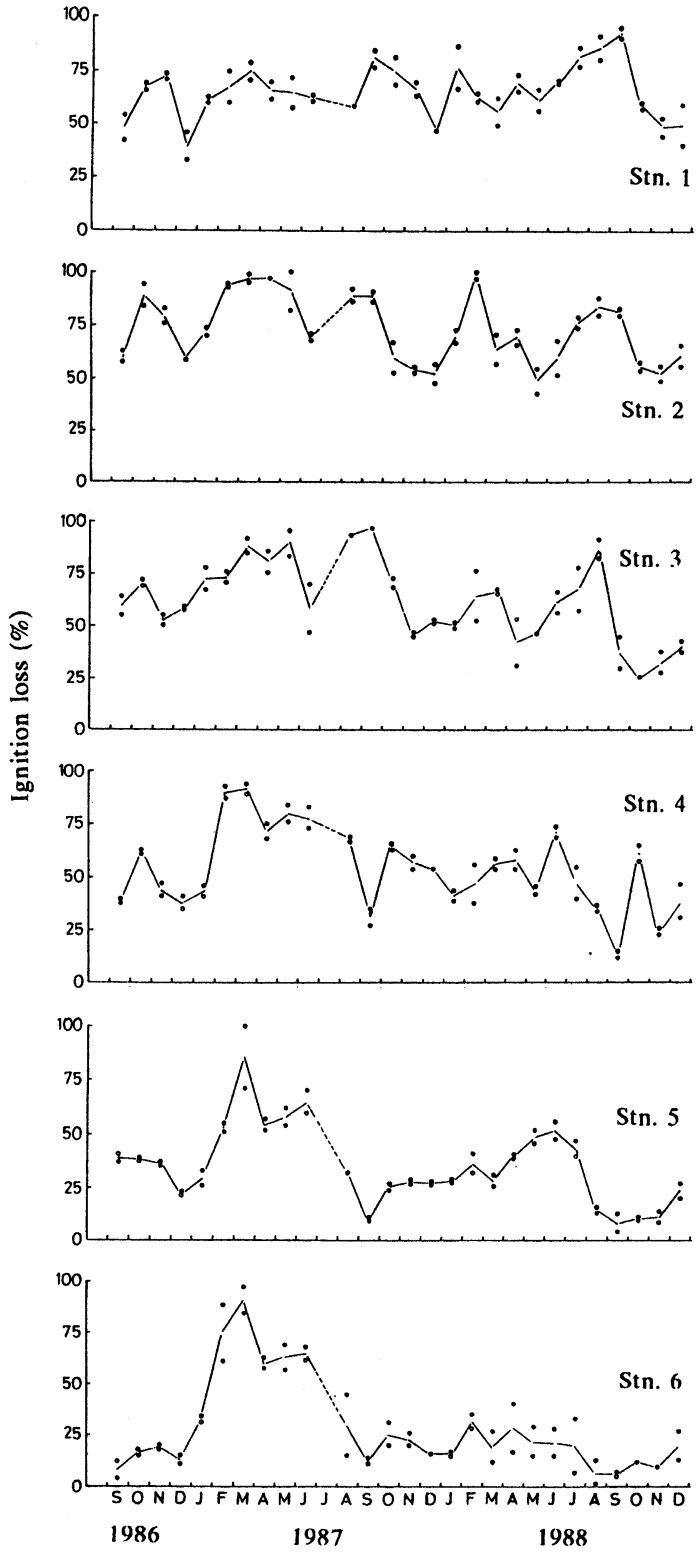

Fig. 5. Seasonal changes of the ignition loss of suspended solid at Stns.1-6 in the main channel of the High Dam Lake. Lines are for averages of the surface (○) and 2 m (●) samples.

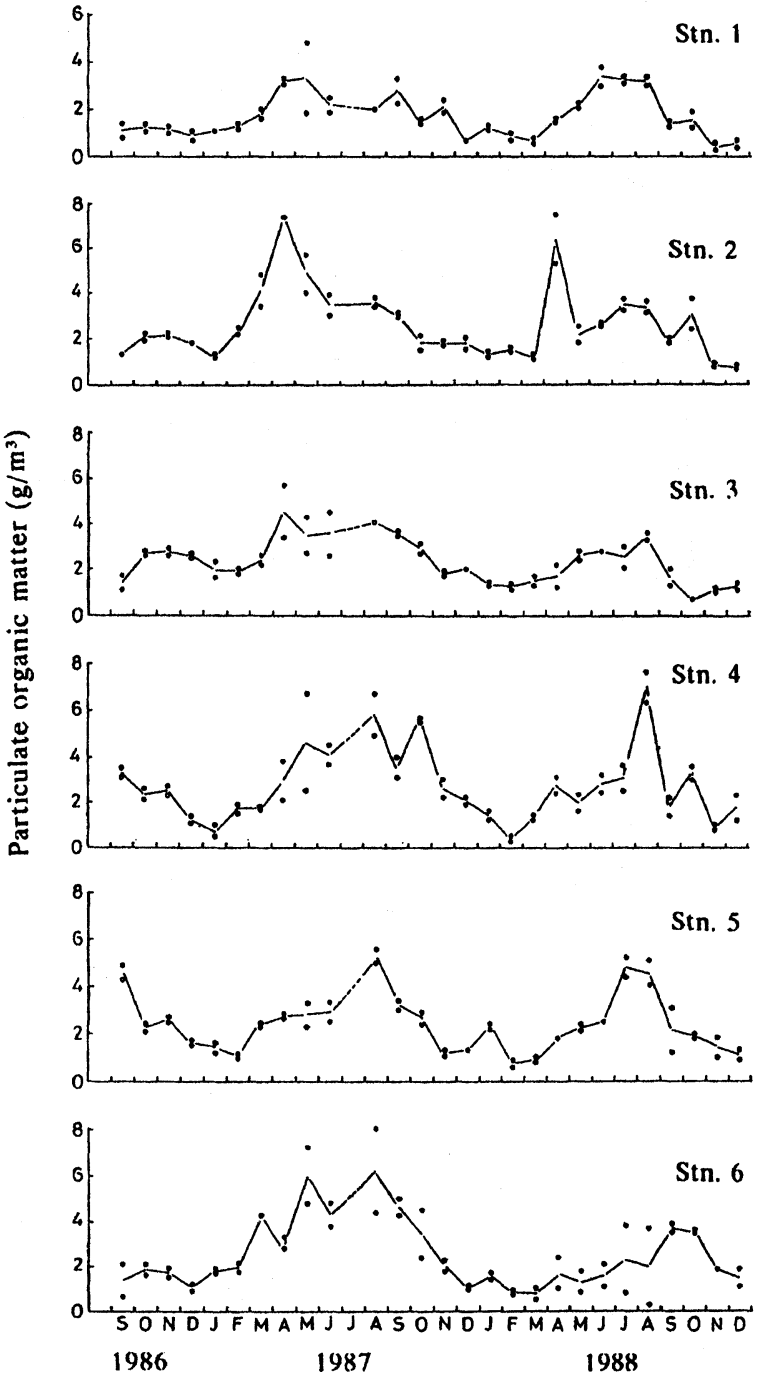

Fig. 6. Seasonal changes of the particulate organic matter at Stns. 1-6 in the main channel of the High Dam Lake. Lines are for averages of the surface (○) and 2 m (●) samples.

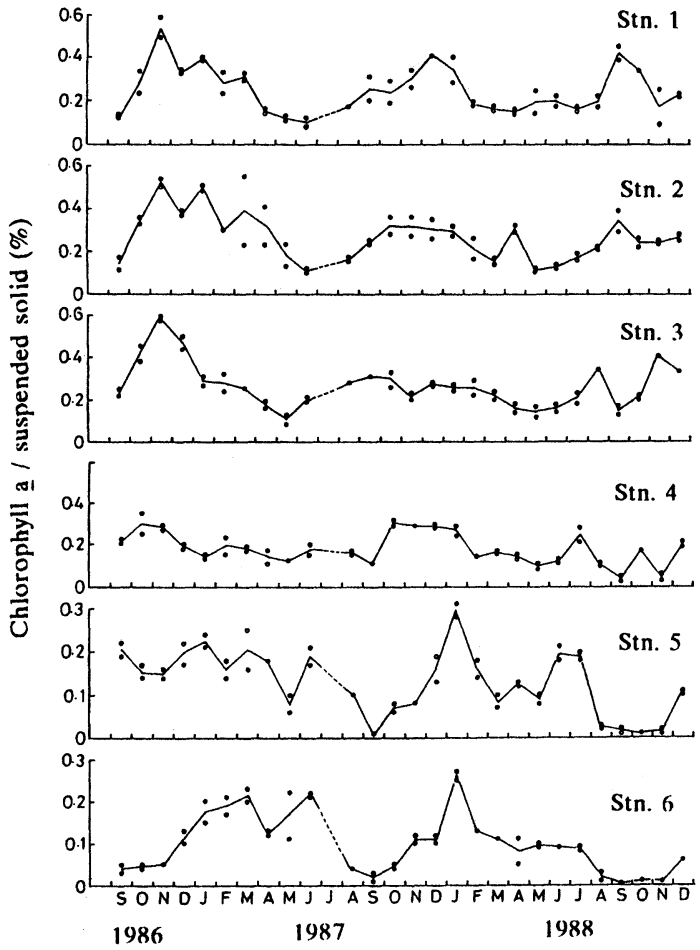

Fig. 7. Seasonal changes of the ratio of chlorophyll *a* to suspended solid at Stns.1-6 in the main channel of the High Dam Lake. Lines are for averages of the surface (○) and 2 m (●) samples.

by frequent changes with lower levels especially in 1988.

Relationships were investigated between the chlorophyll *a* concentration and the particulate organic matter for the surface water and 2 m layer separately (Fig. 8). For both cases, there was positive correlation with considerably scattered data points between the two parameters, and no significant difference was observed between the two cases.

Figure 9 illustrates the relationship between the Secchi disc depth and the amount of suspended solid for all the data of suspended solid in the surface water and 2 m layer from September 1986 to December 1988 at Stns. 1-6. A clear hyperbolic relationship was obtained on a normal diagram and an exponential relationship on a semilogarithmic diagram. The results indicate that the Secchi disc depth was almost directly dependent on the amount of suspended solid in the lake water.

The relationship between chlorophyll *a* and suspended solid was examined separately for the surface water and for the 2 m layer as illustrated in Fig. 10. Positive correlations can be seen between the two parameters, however the data points were scattered very much. About 90% of the data were in the ranges of 1-30 mg/m^3 in chlorophyll *a* and 1-

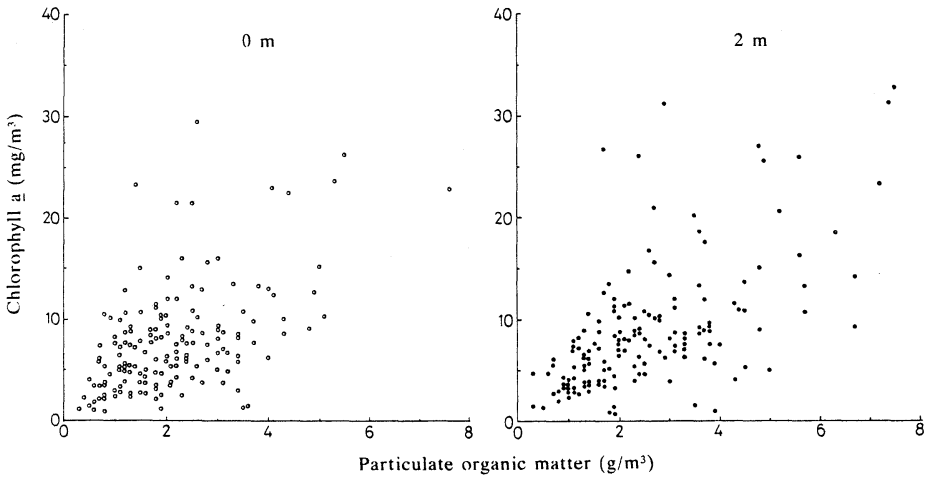

Fig. 8. Relationships between the chlorophyll *a* and the particulate organic matter at Stns.1-6 in the main channel of the High Dam Lake.

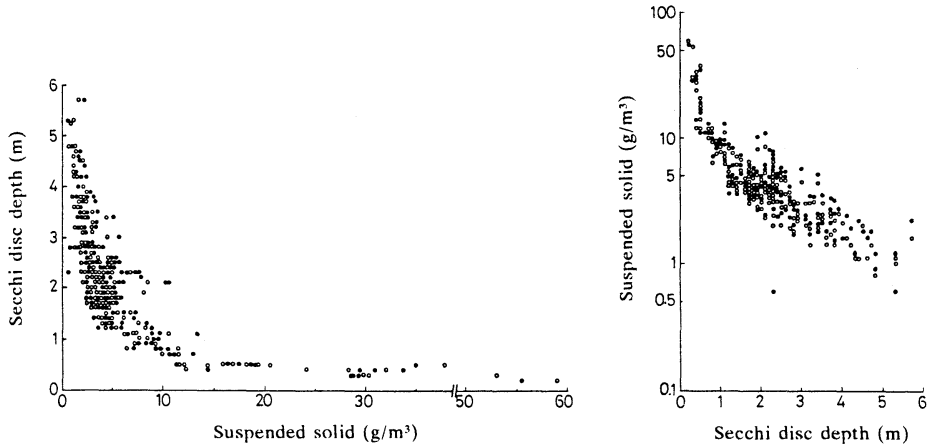

Fig. 9. Relationships of the Secchi disc depth to the suspended solid at Stns.1-6 in the main channel of the High Dam Lake. ○, 0 m; ●, 2 m.

15 g/m³ in suspended solid. There is no significant difference between the relationships in the two layers.

4. Discussion

The seasonal patterns of the Secchi disc depth were similar to those previously reported (OLFAT *et al.*, 1987; OLFAT and ARUGA, 1988) with higher values during the low temperature period and with lower values during the high temperature period. There seems to be a tendency for the Secchi disc depth to be lower in the southern part and higher in the northern part of the lake, which may be correlated with the decrease of suspended solid with water flow along the main channel (Fig. 3).

The levels of suspended solid were generally high during the flood season at Stns. 4-6 in the southern part of the lake. The seasonal patterns of suspended solid were quite similar with a very high peak in August or September at Stns. 5 and 6, and the peaks became lower at Stn. 4. On the other hand,

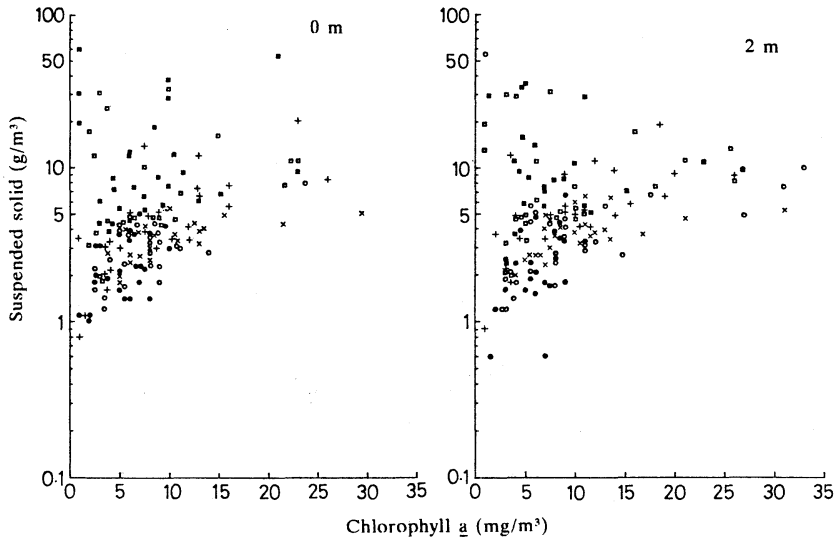

Fig. 10. Relationships between the suspended solid and the chlorophyll *a* at Stns.1-6 in the main channel of the High Dam Lake. ○, Stn.1; ●, Stn.2; ×, Stn.3; +, Stn.4; □, Stn.5; ■, Stn.6.

at Stns. 1-3 the seasonal patterns of suspended solid were quite different from those at Stns. 4-6 (Fig. 3) possibly due to changes in the composition of suspended solid, e. g. the ratio of particulate organic matter to particulate inorganic matter.

In the present investigation a similar trend was obtained in the relationship between the Secchi disc depth and the suspended solid as reported in previous papers (OLFAT *et al.*, 1987; OLFAT and ARUGA, 1988) between the Secchi disc depth and the chlorophyll *a* concentration, in the latter case the data points being much dispersed. This suggests that the Secchi disc depth was more directly dependent on the amount of suspended solid in the lake water.

According to HURST (1957) about 100 million tons of suspended sediments, composed of 30% fine sand, 40% silt and 30% clay, are carried annually with the Nile water on entering Egypt. The quantities of these sediments greatly increase at the beginning of the Nile flood. ELSTER and VOLLENWEIDER (1961) pointed out that the average value of the suspended matter in the Nile at the Egyptian borders during the flood period (August-October) amounted to 1.6 kg/m³. However, after construction of the Aswan High Dam and creation of the High Dam Lake these features were basically changed. In this respect, ENTZ (1980) mentioned that suspended material in Lake Nasser (High Dam Lake) does not exceed a few milligrams per litre and that is mostly organic matter of planktonic origin. This means that the main bulk of suspended clay was sedimented in Lake Nubia. According to the High Dam and Aswan Dam Authority (personal communication) no clay reached the Egyptian water only with high turbidity in the southern part of the lake. EL-OTIFY (1985) reported that the total suspended matter fluctuated between a minimum of 10 mg/*l* and a maximum of 132 mg/*l*, and a gradual increase in total suspended matter was recorded along the main body of the High Dam Lake from north to south in autumn 1982 and summer 1983. The present results for suspended solid are in agreement with EL-OTIFY's (1985) range of fluctuation.

It should be noted that Stns.. 1-3 showed similar patterns of seasonal changes in suspended solid, chlorophyll *a*, ignition loss, particulate organic matter and the ratios of chlorophyll *a* to suspended solid and to particulate organic matter, and Stns. 4-6 showed other similar patterns of seasonal changes in

these parameters, even though sometimes Stn. 4 had seasonal patterns somewhat different from Stns. 5 and 6. It is clearly shown that both the ratio of chlorophyll *a* to suspended solid and the raito of chlorophyll *a* to particulate organic matter are quite variable with seasons and regions in the High Dam Lake. This suggests that particulate organic matter is composed of phytoplankton and other variable organic materials, or at least the chlorophyll *a* content in a cell is quite variable, with seasons and regions, and that the total suspended solid rather than phytoplankton generally plays an important role in determining transparency of water (the Secchi disc depth) of the lake.

Acknowledgements

The authors are grateful to the Captain and the crew of the research boat "El Sadaka" for their great help while collecting the samples. Helpful cooperation of Mr. Abu Wafa Hassen and Mr. Rabi Said are gratefully acknowledged.

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ハイダム湖（エジプト）の主水路に沿う6測点における透明度と懸濁物の季節的変動

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要旨: ハイダム湖（エジプト）の主水路に沿った6測点（Stns. 1-6）で1986年9月から1988年12月まで，透明度，懸濁物，クロロフィル*a*，強熱減量，懸濁有機物を調査した。各測点で表面及び2m深から試水を採取し，分析した。各測定項目及びクロロフィル*a*／懸濁物比ならびにクロロフィル*a*／懸濁有機物比の季節的変動は，ハイダム湖北部（下流）のStn. 1-3，同南部（上流）のStn. 4-6でそれぞれよく似たパターンを示した。また，透明度は懸濁物量と極めて強い相関を示した。クロロフィル*a*／懸濁物比ならびにクロロフィル*a*／懸濁有機物比は，いずれも地域により，季節により著しく変動することが明らかにされた。