The Stagnant Turbid Layer Developed in the Thermocline of Lake Noziri

Masayuki MUKAI*

(*Department of Physics, Faculty of Liberal Arts and Science*)

There develops a conspicuous turbid layer in the thermocline of Lake Noziri in the period from late summer to early autumn almost in the same manner as in Lake Aoki. Also there develops a layer in the thermocline, where the values of pH are of the order 8.0 or more, while those of water in the epilimnion and hypolimnion are of the orders 7.6 and 7.0 or less respectively. These two kinds of layer partly overlap.

Introduction

In the previous paper[1] the author reported on the turbid layers developed in the thermocline of Lake Aoki, which were found in stagnant state in the period from late summer to early autumn every year from 1948 to 1951. And he also reported on the same kind of layer which was found in the year of 1951 in the thermocline of Lake Noziri. He continued the observations at Lake Noziri to make sure of its development, with the measurements of hydrogen ion concentration, the electrical conductivity etc. to find out the correlation, if any, among these factors. He desires to report the results obtained from the observations made in 1952. Fig. 1 is the sketch-map of Lake Noziri. The alphabet in it indicates the place where the water to be measured was drawn out. To recognize the turbid layer the author at first measured the differences of the absorption coefficients of light, which is defined by Lambert's exponential law, with the unit cm^{-1}.

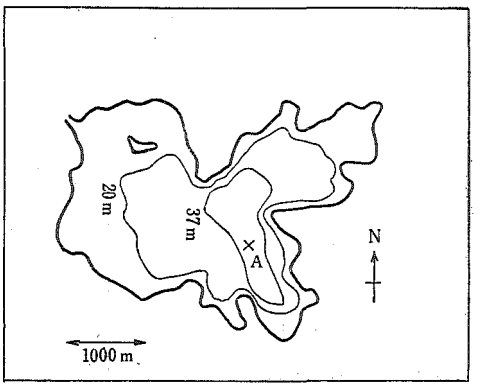

Fig. 1 Sketch-map of Lake Noziri

* Professor of Shinshu University

of the water drawn out of every depth of the lake and that of the distilled water; viz. he measured the values of $\lambda-\lambda_0$ where λ and λ_0 are absorption coefficients of lake water and the distilled water respectively. Thus he measured the vertical distribution of $\lambda-\lambda_0$ with the unit cm^{-1}. The turbid layer is the layer where the value of $\lambda-\lambda_0$ is fairly larger than that of the rest.

The measurements of the hydrogen ion concentration were made by the method of comparing colors. using phenol red, immediately after the drawing of the lake water. The measurements of the electrical conductivity of water were made by Kohlrausch's method. The temperature of lake water varies with the depth, but the measurements of them were performed, after the temperature of all drawn water were reduced to the same temperature.

Results and Discussion

Tables show the results obtained from the observations made in 1952. They are also graphically represented in figures 2, 3, and 4, taking the depth of water as ordinates and the other factors as abscissae.

Table 1 Observed on the 25th of Aug. 1952

Depth (m)	Water temperature (C)	$\lambda-\lambda_0$ (10^{-3} cm^{-1})	Electrical conductivity (relative)	pH
0.	26.5	2.3	1.92	7.6
1.0		5.0	2.03	7.1
2.0	25.6	2.1	1.92	7.2
3.0		2.7	2.01	7.5
4.0	25.6	2.4	1.95	7.5
5.0	25.5	2.8	1.91	7.6
6.0		2.9	1.91	7.6
6.5		2.6	1.98	7.5
7.0	25.5	2.8	1.92	7.5
7.5		2.9	1.92	7.6
8.0	23.9	4.4	1.97	8.1
8.5		4.7	2.00	8.2
9.0	21.2	4.5	2.01	8.3
9.5		5.8	2.00	8.3
10.0	18.8	9.0	2.03	8.2
10.5		10.9	2.08	8.1
11.0	16.1	11.9	2.06	8.0
11.5		12.5	2.07	7.9
12.0	13.7	12.2	2.08	7.7
12.5		9.7	2.05	7.5

13.0		7.4	2.08	7.3
15.0	11.4	6.4	2.07	7.2
15.0		5.2	2.08	7.1
16.0	9.8	5.1	2.08	7.1

Table 2 Observed on the 11th of Sep. 1952

Depth (m)	Water temperature (C)	$\lambda-\lambda_o$ (10^{-3} cm^{-1})	Electrical conductivity (relative)	pH	$\lambda-\lambda_o$ of filtrated water ($10^{3}cm^{-1}$)
0.	23.6	4.7	1.87	7.6	1.1⊙
1.0	23.6	4.4	1.81	7.0	
2.0		3.8	1.80	7.3	
3.0	23.6	4.1	1.82	7.5	
4.0		3.8	1.82	7.6	
5.0	23.6	3.7	1.80	7.6	1.6⊙
6.0		5.1	1.83	7.2	
7.0	23.6	3.7	1.85	7.4	1.5⊙
7.5		4.0	1.84	7.5	
8.0		3.9	1.83	7.5	
8.5		4.0	1.83	7.5	
9.0	23.0	3.7	1.86	7.6	1.5⊙
9.5		5.1	1.84	8.4	
10.0	19.3	5.3	1.89	8.4	
10.25		4.6	1.90	8.2	
10.5		4.6	1.94	8.1	2.5
10.75		4.7	1.90	8.2	
11.0	16.4	4.8	1.90	8.0	
11.25		5.0	1.90	8.2	
11.5		5.6	1.90	8.1	2.8⊙
11.75		8.6	1.99	7.9	
12.0	14.5	14.4	1.94	8.1	
12.25		18.4	1.94	8.1	
12.5		17.0	1.93	7.9	2.2⊙
12.75		17.3	1.92	7.7	
13.0	12,6	16.4	1.93	7.6	
14.0	11.4	12.6	1.96	7.2	2.0
15.0		6.3	1.98	7.0	
16.0	9.6	5.5	1.95	7.0	

Table 3 Observed on the 5th and 6th of Oct. 1952

Depth (m)	Water temperaure (C)	$\lambda-\lambda_0$ ($10^{-3}cm^{-1}$)	Electrical conductivity (relative)	pH
0.	18.9			7.6
2.0	19.4			
4.0	19.4			
6.0	19.3			7.6
8.0	19.3	4.5	1.56	7.5
9.0		4.6	1.56	7.4
10.0	19.1	3.8	1.56	7.6
10.5		4.3	1.50	7.5
11.0	18.8	6.3	1.60	7.5
11.5		7.4	1.63	7.4
12.0	14.9	7.6	1.63	7.5
12.25		6.7	1.67	7.4
12.5		4.8	1.67	7.4
12.75		5.5	1.65	7.3
13.0	13.1	4.8	1.67	7.3
13.25		5.4	1.67	7.4
13.5		5.2	1.68	7.2
13.75		5.7	1.67	7.1
14.0	11.4	4.9	1.67	7.1
14.5		5.9	1.67	7.1
15.0	10.6	4.7	1.73	7.0
16.0		3.2	1.70	6.9
17.0	9.7	3.1	1.68	6.9
18.0		2.8	1.70	6.8

observed on the 5th

observed on the 6th

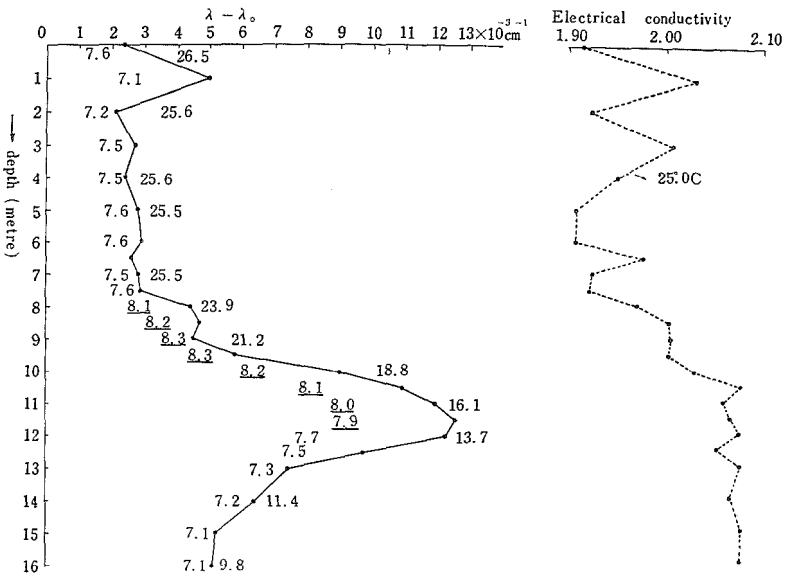

Fig. 2 Observed on the 25th of Aug. 1952

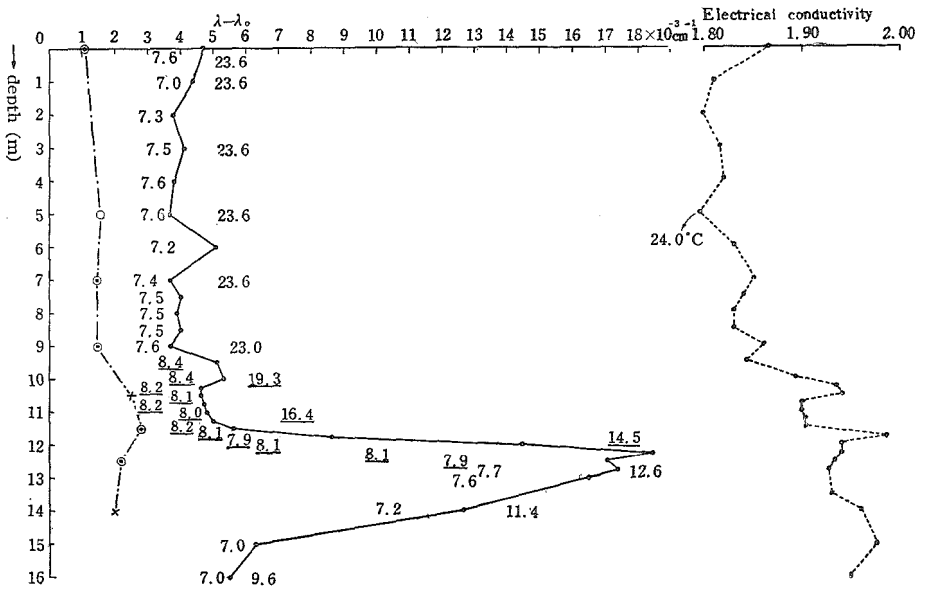

Fig. 3 Observed on the 11th of Sep. 1952

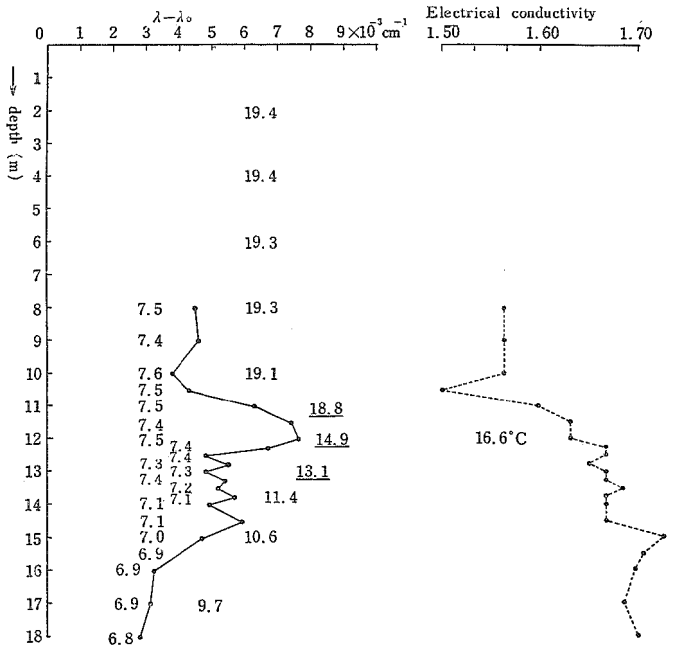

Fig. 4 Observed on the 5th and the 6th of Oct. 1952

Table 4 Number of individuals of phytoplanktons. per 1cc.

depth (m)	*Melosira distans*	*Fragillaria*	*Asterionella*	*Cyclotella*	total
5					
6	329	106	237	23	695
7					
8	354				354
9	259	30	211	21	521
10	379	24	222	23	648
11	303	23	227	35	588
12	271	24	77	16	388
13	270		30	21	321
14	368	25	6	27	426
15	60	485	7	7	559
16	35	296	3	14	348
17	22	242		8	272
18	24	352	12	26	414

The first column of each table shows the depths where the water to be measured was drawn out, the second column the water temperature, the third column the values of $\lambda-\lambda_0$ measured with the unit cm^{-1}. and multiplied by a factor 10^3, the fourth column the electrical conductivity of water the values shown relatively, the fifth column the values of pH, the sixth column of table 2 the values of $\lambda-\lambda_0$ for water filtrated by filter paper for qualitative analysis. The temperature of water which became warmer than that measured in the previous observations, and the values of pH larger than 7.8 are indicated by underlines. The observations were performed on the 25th of August, 11th of September, and 5th and 6th of October; results of them are graphically represented in figures 2, 3, and 4 respectively. The numerals appended to the right side and the left side of the graphs respectively show the water temperature and the values of pH at the depths. The values of pH and the water temperature which are underlined in the tables are also indicated by underlines in the figures. The chain lines in figure 3 show the vertical distribution of $\lambda-\lambda_0$ for filtrated water. Most of them are filtrated immediately after the drawing, which are shown by marks⊙, the rest of them are filtrated about 10 hours after the drawing. The dotted lines in the figures show the vertical distribution of the electrical conductivity of the lake water, the numerals appended to them show the temperature of water when the measurements were performed. The observation of this year was commenced on the 25th of August. The results of it are shown in table 1 and graphically represented in figure 2. A conspicuous turbid layer was observed to be in development in the middle part of the thermocline as was in the previous year.[1] And as was observed in the previous year, there appeared a layer, where the values of pH are larger than that of the other layer.[1] In that layer the values of pH exceeds 8.0. Now the author calls this kind of layer a pH layer in the paper. Both the pH layer and the turbid layer partly overlap, viz. the lower part of the former falls on the upper part of the latter.

Considering that the values of pH in the pH layer are of the order of 8.0 or a little more, with the fact that the dissolved oxygen in the thermocline was measured to be in supersaturation in the previous year at this lake and also at Lake Aoki[1] and also the fact that the similar results were obtained by other researchers,[2] the author also thinks, that the development of the pH layer may be attributed to the generation of phytoplanktons more abundant in the thermocline than in the other layer. And he thinks that there should be certain cases where the existence of certain kinds of

matter in the turbid layer are favourable for the generation of phytoplanktons. Quite similarly with the results of the measurements made in the previous year[1] the values of pH of water in the epilimnion were measured to be of the order of 7.6 and that of water in the hypolimnion neutral with the slight tendency to decrease with the depth in so far as the range where the measurements were performed is concerned.

About the vertical distribution of the electrical conductivity, its value was generally somewhat smaller in the epilimnion, it increased with the depth in the thermocline, reached the largest value at the turbid layer, and then no appreciable change was observed in the hypolimnion within the range where the measurements were performed. Its behaviour much resembled to that observed in Lake Aoki.[1]

Table 2 shows the results obtained from the observations performed on the 11th of September, and they are graphically represented in figure 3. A conspicuous turbid layer was observed to be in existence in the thermocline, as was observed on the 25th of August. But its position was about 2 metres deeper than that observed on the 25th of Aug. The surface levels both on the 25th of Aug. and on the 11th of Sep. were nearly the same, therefore it may be concluded that the turbid layer sank about 2 metres in 17 days. If the conclusion is true the descending velocity of a particle in the turbid layer should be about 12 cm. per day in average.

The graph shows that the turbidity of water steeply increased with the depth at the depth of about 12 metres. And also it was observed that the water temperature at these depths somewhat increased compared with that observed on the 25th of Aug. The increase of temperature surely comes from the autumnal circulation of the lake water. When the circulation reaches this depth the turbid layer must surely have its upper part erased; and the erased part enters into the epilimnion and shall be mixed with the unresting water. The phenomenon of steep increase of turbidity above described was observed in the previous year at this lake, and was also often observed at Lake Aoki.[1]

The author thinks that the steep increase of the turbidity should be attributed to the action of erasure by the circulation of lake water. The author also thinks at present that the descending of the lower part of the turbid layer observed on this day shows that there is also the sinking phenomenon of the turbid layer besides the erasure phenomenon.

About the vertical distribution of the electrical conductivity observed on this day, it may be said that it is of nearly the same behaviour as was

observed on the 25th of Aug. On this day the values of $\lambda-\lambda_0$ of filtrated water was measured, the results of it is shown in figure 3 by chain lines. From these results it may be concluded that the amount of suspended particles which pass through filter papers does not differ much in the epilimnion or thermocline, and also that the most of the suspended particles in the turbid layer are of the order of microns in linear dimension.

Further, the direct counting of the number of individuals of the phytoplanktons in the water drawn on this day was kindly performed by Mr. Kinji Hôgetsu[a] and Mr. Shun-ei Ichimura[b] by the request of the author. Table 4 shows its results. At the depth of about 10 metres the total number of individuals is max. and the numbers of them at the depths of 9 metres and 11 metres are also comparatively large; and these depths fall on the pH layer. The author thinks that is the fact to be attended. He desires that such observations on the planktons with various methods may be accumulated to an approach into the essential parts of the phenomena.

Table 3 and figure 4 show the results of observations performed on the 5th and 6th of October. The conspicuous turbid layer had already disappeared, and only a small one was observed to be in existence. The pH layer had also disappeared. And the autumnal circulation of lake water already reached the depth more than 13 metres. If the turbid layer observed on the 11th of Sep. had continued to sink since that day, it must have been observed at the depth of about 16 metres, but there was no trace of turbid layer at that depth. Therefore, the author thinks it probable, that the turbid layer observed on the 11th of Sep. was erased together with the pH layer, by the circulation of lake water, and the small one observed on this day was a trace or one developed again after the disappearance of the former. About the vertical distribution of the electrical conductivity no serious change in behaviour was observed since the 11th of Sep.

Summary

1) A turbid layer was observed to be in development in the thermocline of Lake Noziri almost in the same manner as in the previous year at this lake and also as at Lake Aoki.

2) Also there developed a layer where the value of pH is comparatively larger than that of the rest, partly overlapping the turbid layer, as was observed in the previous year at this lake and also as in Lake Aoki; its development may be ascribed to the somewhat abundant generation

of phytoplanktons in this layer more conspicuous than in the other layers.

3) The upper part of the turbid layer is generally erased by the autumnal circulation of lake water.
4) Also the turbid layer gradually sinks.
5) The electrical conductivity of the water in the epilimnion was somewhat smaller than that of the water in the hypolimnion, and it increased with the depth in the thermocline, reaching the largest value at the turbid layer as was always observed in Lake Aoki.

The author wishes to thank the Ministry of Education for the Grant in Aid for Fundamental Scientific Research with which he was enabled to make such observations as he liked; also he is grateful to Mr. Takashi Tatsumi,(c) Mr. Toshio Arai,(d) Mr. Kinji Hôgetsu, Mr. Shun-ei Ichimura and the students of Shinshu-University(e) for their helps in the observations.

References

(1) M. Mukai (1952) The Stagnant Turbid Layers Developed in the Thermocline of Lake Aoki and Lake Noziri. (Journal of the Faculty of Liberal Arts and Science, Shinshu Univ. No. 2 P. 1)
(2) S. Yoshimura. Limnology (in Japanese)

(a) Tokyo Metropolitan Univ.
(b) Tokyo-Univ.
(c) Shinshu-Univ.
(d) ditto.
(e) The names of them are Harumi Aoki, Shusuke Kasahara, Kyohei Terada, Junzo Tsukada, Makoto Hoshiai and Iwao Maruyama.