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AN ANALYSIS OF AFFECTION ON THE WATER TRANSPARENCY FACTOR OF WEST LAKE

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Abstract
This paper is a special topic study on affecting the water transparency factor and supervising the water transparency of West Lake, 10 years in succession, and expounds the present situation variable, regularity variable, reasons and improvement methods to the water transparency of West Lake systematically and thoroughly. It gains the conclusion that the water transparency of West Lake bears less relationship with the dissolved substance, and the water transparency is mainly affected by the suspended substance. Because the nutrient substance from the base sludge dissolves out and takes place biological transformation very quick, the phosphorus density has a certain drop, however not affecting the growth and propagation of the algae, and not presenting the phenomena of the phosphorus inhibition . We regard the phosphorus isn't the nutrient element inhibiting the algae growth.

Key words: transparency, algae, TP, Sediment, West Lake.

Introduction

West Lake in Hangzhou is a famous tourist lake at home and abroad. Its region covers 5.66 kilometer square, taking up one-tenth of the whole tourist region in the Hangzhou area. The water quality of West Lake undoubtedly affects the area's tourism and sightseeing. Recently, the city government of Hangzhou has disclosed its administration goal towards the environment in the tourist region, emphasizing points of "four fineness" and "four sense". "Four fineness" means the fine environment, fine service, fine order, and fine administration, while "four sense" means the sense of comfort, the sense of safety, the sense of cleanness and the sense of civilization. The purpose of this goal is to improve and to enhance the quality of the environment in the tourist region, and to make the tourist feel more comfortable.

Water transparency is the greatest audio-visual index evaluating the water quality, and meanwhile is one of characteristic index to the water eutrophication. The beneficial effects of harnessing West Lake water can be directly appraised by increases in transparency. This paper reports on a cooperative study between Japan and China, in which a comprehensive study of water transparency values, accumulated over many years, was undertaken. A monographic study of the transparencies, up to the present condition, will be discussed, along with possible reasons for observed regularities and variations, and for methods for protecting and improving the water in West Lake.

Variation in the water transparency of West Lake

The water transparency of West Lake was surveyed for each month from 1986 to 1995, inclusively. Each monthly value was calculated as an average of weekly measurements (i.e. four regularly spaced measurements) taken during that month. The results of this survey are shown in Table 1.

Table 1. The variable situation of the water transparency (cm) of West Lake during 19861995

Year month		1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	average
1	Average	86.6	56.7	72.3	55.5	61.3	65	64.6	59.0	72.8	78.2	67.2
	Range	55-120	55-60	69-76		47-70	60-72	59-68	52-65	70-75	54-110	
2	Average	100	54	64	50	61.5	65	72.3	65.5	73.3	86.8	69.2
	Range		48-60	58-68		48-72	60-70	62-78	60-72	62.88	70-98	
3	Average	78	50.5	52.8	50	58	54.3	71.0	95.6	77.4	67.3	65.5
	Range	73-90	45-60	40-65		49-68	44-64	64-78	83-100	66-90	55-82	
4	Average	59.3	44.8	47.0	66.8	51.8	50	54.4	72.5	56.3	51.3	55.4
	Range	52-65	39-60	40-50	38-50	49-58	40-58	37-75	60-86	48-64	40-63	
5	Average	45	44	45	55	48	45	54	50.2	51.4	43	48.1
	Range	38-52	41-55	39-51	50-60	42-53	41-49	33-75	45-58	45-60	35-48	
6	Average	39.7	43.7	47	50	45	44.3	43	42.8	47.3	45	44.8
	Range	39-40	41-47	46-51	50-50	38-50	40-46	40-47	40-49	39-60	43-47	
7	Average	35	42	42.8	44	42.8	38.4	39.2	40.7	41.8	43.5	41.0
	Range	30-40	40-43	41-45	38-50	37-52	36-40	34-48	32-52	40-45	40-48	
8	Average	31.5	41.8	38.5	43.3	44	36.8	35.7	42	38.5	33.6	38.6

	Range	29-34	40-43	36-41	35-48	39-50	35-38	30-42	36-50	32-48	28-40	
9	Average	33.5	38	38.8	47.5	39.5	40.3	36.4	33	36.8	39.8	38.4
	Range	32-35	36-40	35-45	40-55	35-43	39-42	32-39	30-39	30-42	36-42	
10	Average	37.0	39.0	35	40.2	40	37.6	35.0	36.5	35.8	38.2	37.4
	Range	-	36-41	30-38	36-48	32-45	37-41	30-40	31-42	34-37	34-40	
11	Average	40.5	50.3	37	41	41.2	45.5	42	43.4	45.6	36.8	42.3
	Range	35-46	46-55	38-40	38-45	38-45	41-49	38-48	38-55	37-60	32-40	
12	Average	47.3	63.7	66.3	55.0	51.0	53.3	44.4	61.7	57.3	51.5	55.2
	Range	45-53	60-70	57-80	45-75	48-55	49-60	42-46	58-68	42-65	45-60	
Y	Average	52.8	47.5	48.9	49.9	48.5	48.0	49.3	53.6	52.9	51.3	50.3

Y: yearly average

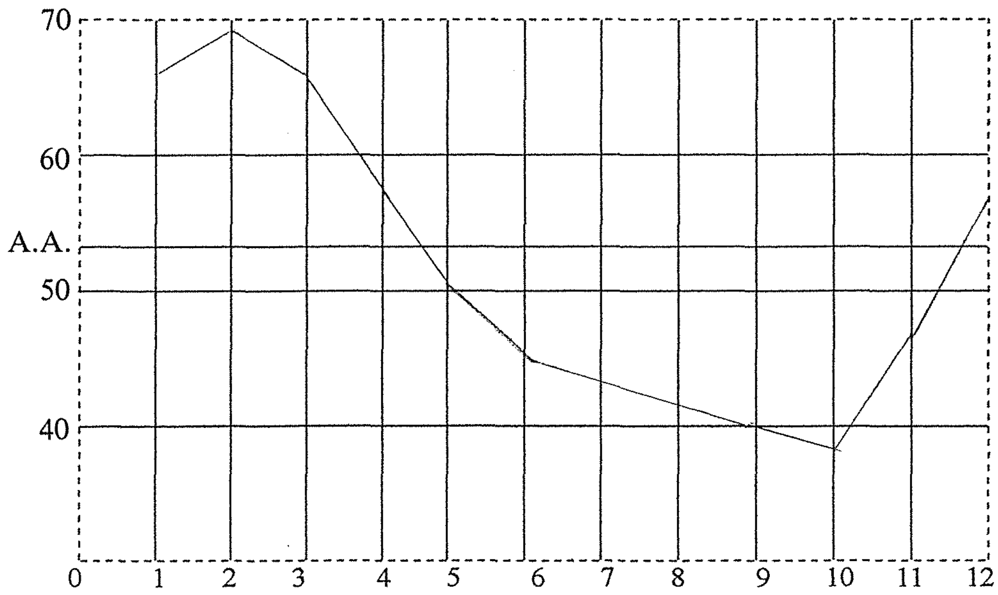
From this table, we can see that:

1.The average annual water transparencies were quite stable over the ten-year period, with a variable range of only 6.1cm. The total average transparency during 10 years is 50.3cm, and the annual average in 1993 was 53.6cm, which was the greatest value; the annual average in 1987 was 47.5cm, which was the lowest value.

2.The average monthly transparencies over the ten-year period were greatly varied. The monthly variable range was 31.8cm. The lowest average monthly transparency (31.8cm) was found for October, and the highest value (69.2cm, almost double that of the lowest) was found for February. A plot of the average monthly transparencies is shown in Figure 1. In this figure, the dashed horizontal line represents the average annual transparency between 1986 and 1995. Figure 1 clearly shows that the transparency was below the annual average during May to November, and higher than average during December to April.

3. The overall water transparency for West Lake was really unstable during the ten-year period. The lowest recorded value was only 28 cm (20 Sept., 1995 and 22 July, 1996), while the highest value was over six times this amount (180cm, recorded on 26 Feb., 1996). Changing conditions of the water environment, along with temperature fluctuations and other influences, can rapidly alter the transparency markedly. Under certain conditions, such dramatic changes can even occur over a matter of days, as shown in the following section (Table 4).

Therefore, although the annual variations in water transparency were quite small, the monthly variations were extremely unstable. As a direct result of this latter instability, the sustainable methods for harness the water in West Lake is very difficult to achieve.



A.A= annual average

Figure 1. The monthly average water transparency (SD) of West Lake for month 1986-1995.

Day -and- night variable regularity of water transparency

The water transparency was recorded at regular intervals during daylight and nighttime hours at locations with high boating activity or low boating activity (i.e. relatively calm regions) in West Lake. The results at each site are shown in Table 2, while Figure 2 shows the average transparencies for high-activity and low-activity regions. From this table and figure, it is apparent that variations between day and nighttime transparencies were different for active and relatively calm regions. In the calm regions, transparency is largely determined by the algae content in the lake. As the variation in algae content was low between day and night, so to be high the variation in transparency. In the boat active region, however, the transparency is largely affected by the amount of sediment sludge stirred up by the boat. Therefore, the transparency was lower during the day, while boat activity was high, and higher during the night as stirred-up sediment began to re-settle. This was particularly evident at Hangfan wharf, which contained large boats with deep draughts. At 11:00 (the height of boating activity in this site) the transparency was recorded to 25cm. By 3:00am, the boating activity had ceased for some time and thus suspended matter had re-settled and the transparency rose to 63cm.

Table 2. Variations in water transparency (SD, cm) of West Lake during day light and night-time periods

Spot	Time	7:30	11:00	15:00	19:00	22:30	3:00	Av.
	Dahua boats shed	68	36	49	35	46	52	47.7
Boats	No. 1 Wharf	54	47	49	46	58	63	52.8
Active	Juvenile palace	68	49	56	60	66	70	61.5
Region	Zongs Wan wharf	56	42	50	46	46	56	49.3
	Hangfan Wharf	58	25	34	40	45	63	44.2
	Lake center	59	46	44	40	53	67	51.5
	Average	60.5	40.8	47	44.5	52.5	61.8	51.2
Boats relative calm region	South of three pools islands	48	46	47	55	55	67	53
	Near Wan Villa	47	47	55	46	50	64	51.5
	Average	47.5	46.5	51	50.5	52.5	65.5	52.3
Yuehu Lake		66	40	41	55	63	70	55.8
Inner West Lake		65	52	65	64	67	70	63.8

Analysis of factors affecting the water transparency of West Lake

Water transparency is determined by a variety of factors, including the levels of plankton, silt, sand, clastic, dissolved organic substance, etc., in the water. Three such factors (dissolved colored substance; plankton or algae content; and other suspended matter) were analyzed for their effect on water transparency. These are discussed in their respective sections below.

Dissolved color substance in the lake water consists mainly of humus and metals. Samples of West Lake water were filtered through a quantitative filter paper and a 0.45u acetic acid fiber filter membrane. In each case, including water samples with original transparencies as low as 28cm, the resultant filtrate appeared colorless. In fact, the transparency of each filtrate approached that of running water (more than two meters). This indicates that the amount of dissolved colored substance in the lake water was insignificant, and its effects on the transparency can therefore be ignored.

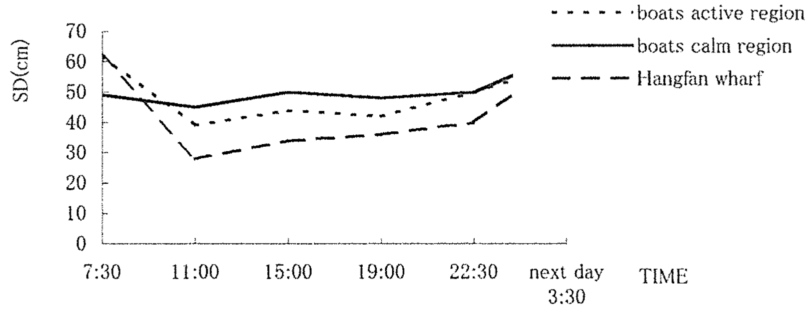


Figure 2. Variations in water transparency (SD) of West Lake during daylight and night-time periods.

In West Lake, plankton algae are very rich. In 1988 to 1989 the annual average algae content was 11,180 cells/L. The composition and content of plankton algae is the main determining factor for water transparency and watercolor. A negative correlation has been shown to exist between algae content and transparency in West Lake, and is shown below:

lnSD=5.84-0.295 lnTA (r=-0.96, n=13)
where TA = algae content (10 /L) and SD = transparency (cm).

As algae growth is determined by objective condition such as sunlight, temperature, nutrient salt concentration etc., algae composition and amount varies according to different seasons. Consequently, transparency also varies in different seasons. Therefore, several objective conditions were analyzed for their effect on algae growth, and are discussed below:

The monthly water temperature and algae content in West Lake were recorded for each month in 1988 and 1989, and are shown in Figure 3. The annual average water temperature was about 18°C. The highest temperature reached was over 35°C, and the lowest was below 0°C. From May to October, the water temperature exceeded 20°C. A positive relationship was found to exist between algae content (TA, 10cells/L) and water temperature (T, °C), and is shown below:

LnTA = 3.40 + 1.23 lnT (r = -0.96, n = 13)

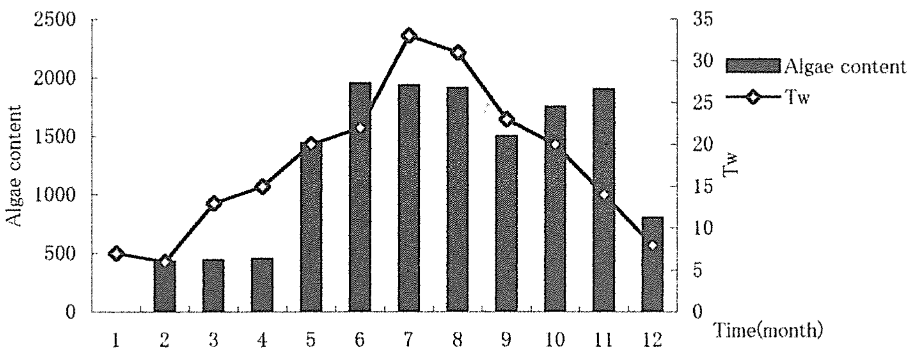


Figure 3. The monthly variation in water temperature (TW) and algae content in West Lake.

Seasonal variations in water transparency were recorded between 1986 to 1996, inclusive, and are shown in Table 3. Taking into account the negative relationship between algae content and water transparency (see above), it is evident from this table that the lowest algae content consistently occurred in the first season in each year (i.e. Jan., Feb. and March).

Table 3. Seasonal variations in water transparency of West Lake.

Year	first season	Second season	third season	Fourth season	annual average
1986	88.3	48.0	33.3	41.6	52.8
1987	53.7	44.2	40.6	51.0	47.5
1988	63.0	46.3	40.0	46.1	48.9
1989	51.8	57.3	44.9	45.4	49.9
1991	61.4	46.4	38.5	45.5	48.0
1992	69.3	50.5	37.1	40.5	49.3
1993	73.4	55.2	38.6	47.2	53.6
1994	74.5	51.2	39.0	46.2	52.9
1995	77.4	46.4	39.0	42.2	51.3
1996	112.7	64.5			
Differential	60.9	20.3	11.6	10.5	

This is the winter seasons in Hangzhou and it is greatly affected by the cold atmosphere from the north. Each year, the frequency and strength of this cold atmosphere varies, such that the weather of the first season highly changeable, causing a great disparity for the surviving content of algae. For example, while the algae content in the first season of 1989 reached 1137 x 10 cells/L, the algae content in the same period for 1996 was only one tenth of this (100 x 10 cells/L). Correspondingly, the transparency for this season in 1996 was about twice as high (112.7cm) as that in 1989 (51.8cm).

The most dramatic changes in transparency, and therefore algae content, occurred between the first and second seasons, i.e. between March and April. At the beginning of the middle and last ten day period in March the water temperature remains stable about 10°C. At this point the weather begins to warm, resulting in an increase in water temperature and consequently a large amount of algae growth and reproduction. However, this rapid algae growth was not always consistent. For example in 1985 and 1986, a late cold front reduced the temperature in March to the point that snow fell. This resulted in death of most of the algae, along with a dramatic increase in transparency to such levels that the bottom of the lake could be seen. In 1996, two snowfalls on the 5th and 18th of March reduced the algae content from 2000 cells/L to 570 cells/L, and the transparency of Outer Lake reached 178cm, while in 1985 the transparency reached 180cm.

The lowest temperature in which algae can reproduce is about 10°C, with the atmospheric temperature being over 14 °C for two or three consecutive days. For example, between Feb. 5th to 12th in 1996, the atmospheric temperature reached 14.8 °C for two consecutive days, and the water temperature rose to 9 °C. At this point algae began to reproduce, and the water transparency dropped from 120cm to 110cm. These latter observations can be seen in Table 4, which gives a more comprehensive documentation of temperature and transparency fluctuations during the first season of 1996, and March and April of 1995.

Table 4 . Water transparency (cm) variations with temperature in West Lake.

DATE	TRANSPARENY	WATER TEMP.	AIR TEMP.	HIGHEST TEMP. IN THE COURSE	LOWEST TEMP. IN THE COURSE	
1996.1.8	55.0	7.1	2.4	6.4	-0.7	
1.15	68.0	5.5	4.1			
1.22	90.0	3.0	3.4	2.9	0.0	
2.5	120.0	7.0	4.9	14.8	2.5	
2.12	110.0	9.0	14.8	18.3	-1.2	
2.26	160.0	4.0	4.3	10.9	3.5	
3.5	110.0	9.0	10.9			
3.18	130.0	11.0	4.5	8.0	5.2	
3.25	178.0	7.0	5.2	11.7	6.1	
4.1	155.0	9.0	6.1	17.0	9.4	
4.10	115.0	11.0	9.4	21.1	8.3	
4.17	82.0	15.0	21.1	22.0	13.4	
4.29	70.	20.0	21.7			
1995.3.7	82	12.0	13.6			
3.14	70	12.0	11.8			
3.21	55	14.5	17.7	17.7	6.6	
3.28	62	15.0	11.8			
4.4	63	12.0	10.6	18.4	10.5	
4.10	48	15.5	10.7			

From Oct. to Dec. the water temperature obviously dropped down in every years, and the monthly average water temperature is 21.3 °C in Oct. and 16.6°Cin Dec.. It was almost approaching that of Apr. and May, but the algae content in these season obviously exceed that of April and May because of the sunshine hours more than in these seasons, relatively. Oct. and Dec. of this region are the charming autumn and good climate seasons, and it has less rainy day during this period, the time of sunshine become longer, and the water temperature of the lake don't drop to below the low limit temperature of algae growth.

Table 5 shows that the phosphorus contents of West Lake are decreasing year by year. The annual concentration of phosphorus in 1994 dropped to 36.8% of that in 1986 on the average, and went down 0.042 mg/l as the concentration of phosphorus. But the transparencies in each year are almost same. The correlationship between the water transparency and the concentration of phosphorus in West Lake is as follows:

$$\ln SD = 8.63 - \ln (T\text{-}P) \qquad (r=0.99)$$

where SD is the water transparency (cm) and T - P is the concentration of total phosphorus (mg/L).

Table. 5 Annual average water transparencies and phosphorus levels in West Lake.

Year	transparency	phosphorus	variable range
1986	52.8	0.114	0.049-0.189
1987	47.5	0.110	0.080-0.128
1988	48.9	0.126	0.094-0.168
1989	49.9	0.111	0.075-0.145
1990	48.5	0.106	0.069-0.133
1992	49.3	0.127	0.072-0.217
1993	53.6	0.080	0.038-0.126
1994	52.9	0.072	0.044-0.127
on an average		0.106	

When phosphorus is 0.114mg/l, the transparency is 49.3 cm. When phosphorus is 0.072mg/l , the calculated result of the transparency should be 77.9cm , but the fact is that the measured value was 53cm , the phosphorus couldn't enhance the water transparency . As indicated above, it expounded that only if the water phosphorus on an annual average exceeds 0.072mg/l, the condition can content with the needs of reproducing algae. The phenomenon of the phosphorous restraint fails to appear.

According to some reports of documents, it is required to consume 0.009g phosphorous, 0.063g nitrogen, 0.01g hydrogen, 0.358g carbon and 0.496g oxygen for algae to increase one gram. Owing to the investigation of the algae in West Lake, the annual mean primary production was 2334 mgC/m^2.day. That is, one gram organic carbon is corresponded to approximately amounts to 20 gram plankton algae as the fresh weight, it means a water column every square meter can produce 46.7 gram plankton algae every day, which requires to consume 0.42g phosphorous. The phosphorus content in West Lake was 0.106mg/l, corresponding to 0.106g every square meter. If the water depth was 1.6m, the phosphorus content every square meter was just only 0.17g. It is still less than one half of the phosphorous content which those algae require. Algae, however, are still glowing continually by the supplement of the phosphorus released very quickly from the bottom sludge and silt and the decomposition of living things. Both processes maintain the algae growth, and kept the balance of phosphorus in water. The concentration of the dissolved phosphorus in bottom sludge indicates in Table 10. As indicated above, the resource of phosphorous in West Lake water was very rich, and the water possessed the condition of the transformation. In spite of the low phosphorous content in water, the phosphorous content was still the nutrient element limiting the growth of algae at present.

The phosphorous is the main element that the cells of algae metabolize and self-duplicate nucleotide. The phosphorous density in water takes an important part in the reproduction of plankton algae. The algae content is positive interrelated with phosphorus (Figure 4). It is not only the increasing density of phosphorus cause the algae content arise, but also the increase of the algae content in water will promote

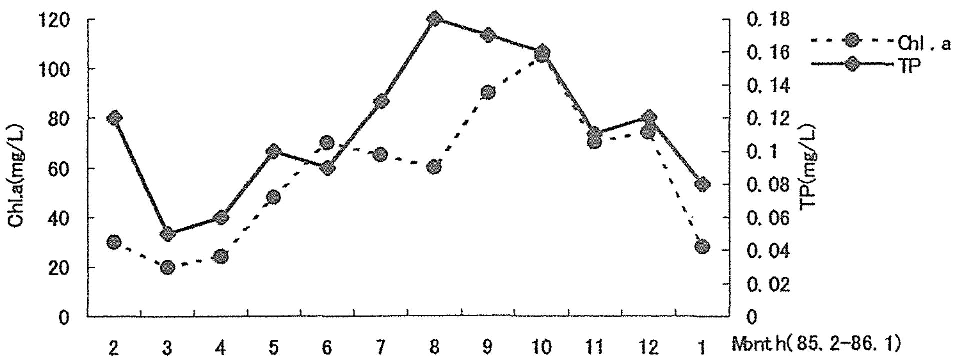


Figure 4. Monthly variation in average chl. a and T-P levels in Outer Lake

the density of phosphorus arise conversely due to the death decomposition of algae, and so both relationship is mutual between algae content and phosphorus .

Table 6. The relative comparison between the transparency of the different lake water and their chlorophyll

Region	Chlorophyll-a concentration (μ g/L)						Relative formula between SD And chlorophyll-a	SD unit in formula
	100	80	60	50	40	20		
Inner North Lake	43.1	47.0	53.5	57.9	63.6	85.5	lnSD=5.73 - 0.426 lnChl-a	cm
Inner West Lake	49.0	54.1	61.5	66.7	73.6	100.2	lnSD=5.94 - 0.444 lnChl-a	cm
Outer West Lake	48.3	51.8	56.7	60.0	64.3	79.8	lnSD=5.31 - 0.311lnChl-a	cm
Lakes of Sweden	51.1	58.0	68.3	75.8	88.2	128.0	lnSD=0.85 - 0.571 lgChl-a	cm
Lakes of Japan	55.6	64.2	77.5	87.2	100.9	158.4	lnSD=2.41 - 0.651 lnChl-a	Cm, r=0.96

* The results of an investigation of 24 lakes in Japan
(Xian Qi Shou Hong et al. the environmental pollution institute in Japan)

Table 6 shows that the water transparency against unit chlorophyll amount of the three lakes containing West Lake are lower than that of lakes in Japan and that of lakes in Sweden (Xian qi shou hong, Forsberg and Riding et al.). Furthermore, it illustrates that the suspended substance except algae in West Lake is more than that of the lakes in Sweden and Japan.

The water transparency of West Lake is very intimately related with the suspended substance

$$\ln SD = 6.75 - 0.834 \ln SS \qquad (r = -0.98, n = 13)$$

where SD is transparency (cm) and SS is suspended substance (mg/L)

If the content of the chlorophyll represents the that of algae, the chlorophyll every gram amounts to the dry weight of 94.4 mg, through the test measure and the result of calculation lists as follows.

Table 7. The differential between suspended substance (SS) , water transparency (SD), cholorophyll a (Chl. A), and algae content in West Lake.

SD	SS	chla	weight of dry algae	Differential	remarks
30	55.04	463.06	43.68	11.36	
35	45.76	282.22	26.65	19.11	lnSD=6.7456-0.8344lnss
40	38.99	183.71	17.33	21.66	SD- cm
45	33.86	125.82	11.87	21.99	SS- mg/l
50	29.84	89.70	8.5	21.34	lnSD=5.3113-0.3112lnchla
60	23.99	49.93	4.71	19.28	SD- cm
70	19.94	30.42	2.87	17.07	chla- u g/l
80	16.99	19.81	1.87	15.12	

Table 7 clearly shows that the total amount of suspended substance and the dry weight of algae have some relationships. In West Lake, however, the organic clastic and suspended sludge particles except algae make to form the background for transparency. Therefore, at the case of same density of algae, the water transparencies in West Lake are often lower than that of the lakes in Sweden and Japan.

The sludge particles of West Lake are distributed in surface layer, middle layer and bottom layer. The surface layer is the most porous, the specific gravity of natural wet soil is only 1.06, the specific gravity of the Outer Lake sludge on the average is 2.26. The particle diameter composition and subsiding time lists as follows:

Table 8 . The particle composition and subsiding time of surface sludge in main lake region

particle diameter content lake region	0.25 - 0.05	0.05 - 0.01	< 0.01	among < 0.001
North inner lake	15.83	35.72	48.05	12.54
West inner lake	13.10	42.60	44.04	11.78
Outer lake	13.85	39.85	39.85	12.53
Subsiding time	in 15'	15'-6h	6h-25h	26day +2h27'

* the subsiding time is counted according to subsiding the lake base , the water depth 1.5 meter , specific gravity 2.3 , water temperature 20°C

Table 8 states that the 40% particles need more than 6 hours to sink the bottom, among which 12.5% particles need over 26 days to sink. It is thus obvious that the particles of suspended sludge are an important factor affected transparency and are reason resulted from the great variation of the transparency day-and-night.

On April 26th in 1988, the test for transparency dropped 10-20cm in the boat channel after DA HUA powered boats sailed. And the range of transparency is 30 – 50cm; (water depth 1.7m, more than 0.9m draught), and the test transparency in the rear channel of the pleasure-boat dropped about 9 - 10cm (its water depth 1.6m), and the range of testing channel 20 – 30cm. In the wharf of HU BIN, the test state are listed as follows:

Time	Transparency	Turbudity	State of lake
6:00	98cm	15	no boats activity
8:20	20cm	140	one hour after boats sailed
9:20	5cm	600	at moment DAHUA powered boats just left

The comparison between boats active region and boats calm region is as follows:

Table 9. The comparison of transparency and turbidity between boats active region and boats calm region of West Lake.

Region	SD (cm)	Turbidity	Water color	Water depth (m)	Description
No.1 wharf before Boats sailing	65	20	yellowish green	1.14	
Powered boats channel in the lake	52	24	turbid	1.55	10 minute later after boats sailed
outer Broken Bridge	70		pale green	1.50	boats calm region
ZONGSHAN Wharf	55	22	yellowish green	1.34	test at 10:00 am
HUAGANG Wharf	60		yellowish green	1.55	test at 10:30 am

Above indicated examples clearly stated that the activity of boats or boats exerted a tremendous influence on the water transparency. Whether nearby wharf or boats channel, the tested transparency was lower 10 - 20cm than that of the boats calm region, the water transparency was different because of the different water depth. The boats in HUAGANG Wharf were larger and more than those of ZHONGSHAN Wharf. The water depth, however, in the HUAGANG Wharf was deeper, and on the contrary its transparency was better than that of ZHONGSHAN Wharf, the water depth appropriately increase so as to reduce the affection of bottom sludge on the transparency. It is suggested that the water depth on the average in West Lake is 1.8 - 2.0m, and the pleasure-boats with draught are controlled in less than 0.65m.

The plan of the test: Use two large ceramic vats, its diameter is 1.2 m and its highness is about 1.0 m, put into the pre-mixed well-distributed sludge of West Lake separately and pour in the water of West Lake up to 60cm depth along vat wall.

For the test group, the vat was stirred man-made three times every day at 8:20, 11:30, 11:30, 15:30, each times took 20 second; For the contrary group, not stirring with it. The next day at 8:00am, we begun to sample the water, and the test results on the three day in succession list in following Table 10.

As shown in Table 10, The water transparency after stirring the vat of the test group was only one-fifth before stirring it, however the contrary group increased by two times. The turbidity of the test after stirring increased by a factor of 15, the COD increased by two times and the phosphorus increased by a factor of 2.3, and amino acid nitrogen increased by a factor of 7. On the contrary, the contrary group at a standstill made original algae and part of suspended substance sink, made the water transparency increase, and made turbidity drop. However the nutrient matter in base sludge dissolved out, which made COD and amino acid nitrogen slightly increase than original time. Normally the phosphorus should reduce with algae precipitation, however the test result of phosphorus had risen slightly, which stated that the dissolving phosphorous dissolved obviously.

The above test was made at a standstill, in fact the wind, lake wave, boats and ships activity and so on would affect and make the exchange velocity of sludge and water interface increase. From the above mentioned, we could see that the base sludge had some part not only in the re-suspended micro-particle preventing the sunlight from penetrating the water but also the nutrient matter dissolved from the sludge prompted the algae reproduce, so it served a dual purpose. Even thought the present content of nutrient matter in water occurred insufficient during the vigorous season of reproducing algae and the season of higher primary productivity, the present content of nutrient matter could gain the quick dissolution of base sludge and gained the supplement from the live-being dead body. Therefore, in order to control the overgrowth of algae, we not only reduce the nutrient salts in water but also drop the dissolving velocity of the base sludge and restrain the transformation ratio of suppression. As a result, to remove excessive sludge and to increase the water depth are effective measures.

Table 10. The effect of stirring base sludge on several water quality parameters

Item	SD cm		turbidity		COD mg/l		T-P mg/l		Amino acid nitrogen	
Results / groups	before stirring	after stirring	before after	stirring stirring	before stirring	after stirring	before stirring	after stirring	before stirring	after stirring
test group	25	5	55	440	8.8	25.42	0.105	0.346	0.092	0.684
contrary group	25	52	55	28	8.18	8.45	0.110	0.140	0.084	0.094

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Conclusions and recommendation

Conclusions

During 1986 - 1995, ten years in succession, the water transparency of West Lake was stable and arises slightly, but the variable range wasn't wide. The transparency of the Outer West Lake on an average during 10 years was 50.3 cm, the peak transparency 53.6cm (in 1993), the lowest transparency 47.5cm (in 1987). The differential between them was 6.1cm.

The annual water transparency of West Lake rises and falls very greatly, the peak month transparency on the average belonged to Feb., its value was 67.2cm; the lowest month transparency on the average belonged to Oct., its value 37.4cm. The month that its transparency on the average is lower than general average line had from May to October and December, total seven months. The transparency of Oct. month was the worst, which not only related with temperature and nutrient salts in water, but also related with the sunshine.

As the water depth of West Lake was shallow, and its storage capacity was small and the buffer ability was also poor, the transparency wasn't stable. The peak transparency reached 180cm (26 Feb., 1996), the lowest only 28 cm (20 Sept., 1995 and 22 July, 1996). Sometimes during one week, the transparency rose and fell more than 30cm (from 18 March, 1996 to 25 March, 1996), it rose 40cm (from 1st April, 1996 to 10 April, 1996), which couldn't make the effect of water harness last and enduring.

In the low temperature season of early spring, so long as the atmospheric temperature of continuous two days on the average exceeded 14°C, the water temperature rose to 9~10°C, the water transparency would drop obviously. On the contrary, the temperature in March descended on a large scale and even fell snow, the transparency would rise on a large scale and even you could see the bottom of the lake. The above exposition shows clearly that the water temperature that the algae began to reproduce in West Lake water was about 10°C, and the algae which just begun to grow in reproductive period was sensitive to the variation of the temperature acutely.

The nutrient matter needed for the algae in West Lake water not only depended on the density of the water, but also on the dissolving velocity of nutrient matter in base sludge and the transformation velocity of live-being. Because the base sludge that still was stirred in West Lake was very rich and fertile, it was the main inexhaustible nutrient sources. Therefore, even if the phosphorus in water was very low, the reproduction of the algae still couldn't be restrained. The phosphorus in water on the average in 1994 was only 0.072mg/l, the water transparency couldn't be improved yet. Seeing that the above mentioned situation, to reduce the nutrient salts in water was very important, however it was only a temporary cure, but dealing with the nutrient warehouse and cutting off the nutrient supply was a real permanent cure.

The color substance dissolved in West Lake water is a little, which couldn't affected the transparency at all. The water transparency mainly depended on the content of the suspended substance. In general, the suspended substance except for algae in West Lake water was about 1020 mg/l, which make the water except for the algae have an background transparency. The background transparency in boat active region descended 10～20cm and that in boats calm region descended 5～10cm. Its influential ratio was up to 30%.

The suspended substance except for the algae in West Lake water was the main substance suspended from the base sludge afresh, and its reason for the suspending matter was the active and boats. The activity of boats made an great different in transparency day- and-night . Sometimes the transparency in Hang Fan Wharf at 11:00 am was only 25cm, and at the same time the transparency in other water area was more than 40cm.

The sludge particles of the surface layer in West Lake were very thin, and its sedimentation rate was very slow. When the water depth was 1.6m and water temperature was 20℃, the 39.9% particles in suspended sludge of surface layer in Outer Lake afresh needed more than 6 hours to subside the bottom, which of 12.5% particles needed 26 days to subside the bottom.

Even at a standstill, the nutrients in bottom sludge have released into the water, continuously. And the BOD substances have dissolved out 0.01mg/l on the average in each day, If the water is mixed slightly, the dissolving velocity of BOD substances increase by two-fold At the case of phosphorus, the velocity is increased by 230%, and amino acid nitrogen by seven times.

Recommendations

In order to reduce and control the dissolution of the nutrient matter from the base sludge, we need to dredge and excavate the sludge in the top and middle layer. The depth of dredge in the Big Powered Boat Wharf are 2.20～2.40m, the dredge radius is 80 m; the channel depth of the Big Powered Boat is 2.0～2.2m, and its width 100m, the average water depth of other lake area in the Outer Lake is 1.8m, that of the West Inner Lake and the North Inner Lake are 1.6m .

Seeing that the area along the bank and causeway of West Lake is especial shallow, in order to protect the bank and causeway and prevent the lake from being dredged deeply. We suggest that the Big Powered Boat Wharf should be 1015 m away from the bank. The Big Powered Boat should sail in regular channel and carry out the legislation administration. The draught of tourist boats in the average in the lakes should be less than 0.65m, and the peak draught can't exceed 0.8m.

In order to improve the water content in Sept. and Oct., we should make the most of the diversion works. During the two months, the standard of the diversion transparency should be controlled in 60cm, and descends 10cm than the conventional water in order to increase the days of the diversion.

Install one automatic recorder of the water level and transparency in the diversion pump station in order to reflect the regularity of the spring tide and the variation of water content in Qian Dan River. To set up one automatic monitor station about the parameters of the water quality, such as temperature, transparency, pH and so on in order to make known and have a good command of the variable regularity of water quality really and promptly.

Plant and grow the submerged plant such as the eel grass, verticillate leaves and black algae, which can not only absorb the nutrition of water, but also restrain the suspension of base sludge afresh as well as beautifying the environment of lake bottom and serving a several purpose.

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