ISSN 1070-3632, Russian Journal of General Chemistry, 2011, Vol. 81, No. 13, pp. 2653–2657. © Pleiades Publishing Ltd., 2011.
Original Russian Text © G.T. Frumin, Zhan-Zhan Khuan, 2011, published in Ekologicheskaya Khimiya, 2011, Vol. 20, No. 1, pp. 11–16.

Trophic Status of Fresh-Water Lakes in China

G. T. Frumin and Zhan-Zhan Khuan

Russian State Hydrometeorological University, St. Petersburg, 195196 Russia

Received February 21, 2011

Abstract—In the article the trophic status of thirty one fresh-water lakes of China was described. Four lakes are characterized as mesotrophic, seventeen lakes have eutrotrophic status, and ten lakes are hypertrophic. Critical phosphorus loading for five biggest fresh–water lakes was calculated. The relationship between average and maximal depth of 141 lakes was revealed.

DOI: 10.1134/S1070363211130044

There are more than 2.800 lakes with an area of 1 km^2 each, and 130 lakes with an area of more than 100 km^2 each in China. Moreover, the country has a lot of artificial reservoirs and water storages. They are divided into freshwater and saline. Large lakes are situated mainly in the middle and lower ones reach the Yangtze River and the Qinghai-Tibet Plateau. The largest freshwater lake in China's is Poyang, the largest saltwater lake is Tsinhayhu.

20 lakes in China dry up each year. Over the past 50 years country has lost more than 1000 natural water reservoirs. This is almost 10000 km^2 of the water surface. The main reason of this is the active development of industry. China over-uses fresh water. The lakes are drained to create new areas for agriculture. The forests along the shores of reservoirs are cut down that leads to shallowing of lakes.

Industrial waste water entering the lakes contain chemical compounds came from metallurgy, textile, pharmaceutical, food, pulp and paper industries. Nitrogen and phosphorus contained in the municipal and agricultural runoff also come to the lakes. This results in significant accumulation of pollutants and nutrients. About 80% of the lakes in the valleys of the Yangtze River "bloom", and this creates ideal conditions for algae reproduction. When dying-off they consume a lot of oxygen from the water mass. The lack of oxygen kills shellfish, fish and other inhabitants of the lakes. As a result, the lakes turn into swamps. Thus, the main ecological environmental problems of the lakes of China are toxicophication and eutrophication.

Eutrophication is a natural process of evolution of a reservoir. Since its "birth" under natural conditions, the water reservoir passes through several stages of its development: at the early stages: from ultraoligotrophic to oligotrophic, then mesotrophic and at last it becomes eutrophic and hyperevtrophic. The water reservoir "ages" and dies forming a swamp. However, under the influence of economic activity this natural process has some specific features, i.e. it becomes anthropogenic. The speed and intensity of the productivity of ecosystems increase dramatically. Thus, in vivo the eutrophication of a lake takes about 1000 years or more, while under human impact this can happen a hundred or even a thousand times faster. For instance, such large water bodies as the Baltic Sea, Lakes Erie, Ladoga and Tahoe transfered from one trophic status into another during 20–25 years. This process has involved a lot of the largest freshwater lakes in Europe, the USA (Great Lakes of America), Canada and Japan [1]. As eutrophication has become a serious global environmental problem, the UNESCO has started working on monitoring the inland waters, controlling the eutrophication of the globe.

In connection with the above mentioned, the purpose of this study was to assess the trophic status of some freshwater lakes in China. The data from ILEC (International Lake Environment Committee), as well as data taken from publications [2, 3] are used for the study.

Grigory Tevelevich Frumin, Dr. Sc. (Chem.), Prof., Department of Ecology, Russian State Hydrometeorologic University. Scientific areas of focus: toxicology, eutrophication and chemical pollution of natural waters, risk assessment.

Zhan-Zhan Khuan, post-graduate student, Department of Ecology, Russian State Hydrometeorologic University. Scientific areas of focus: limnology.

Table 1. Limnological characteristics of the lakes of China

The lake	*Chl a*, mg·m^{-3} [a]	SD, m [b]	TP, mg·m^{-3} [c]
Poyang	1.34	1.1	97.0
Dongting	0.6	0.8	119.0
Taihu	47	0.8	52.0
Hongze	3.4	0.2	140.0
Chaohu	15	0.2	105.0
Tianezhou	3.1	0.63	23.0
Zhangdu	3.8	0.85	46.0
Moshui	81.7	0.33	1448.0
Longyang	85.5	0.48	955.0
Sanjiao	75.5	0.77	326.0
Dongdongt	3.2	0.75	50.0
Laojiang	13.9	0.66	80.0
Shijiu	6.3	1.04	66.0
Niushan	2.9	2.6	44.0
Longgan	0.8	0.50	49.0
Junshan	1.3	2.18	32.0
Sanligi	41.1	0.51	176.0
Qingling	146.1	0.46	230.0
Nanhu	126.4	0.33	333.0
Dianshan	17.1	0.51	255.0
Hongxing	74.8	0.52	249.0
Huama	19.1	0.70	63.0
Wuchang	7.1	0.91	62.0
Yangcheng	16.7	0.77	108.0
Gehu	41.3	0.47	248.0
Honghu	46.5	1.24	75.0
Baoan	28.6	1.24	95.0
Houguan	18.0	1.27	61.0
Banghu	1.3	1.15	8.0
Dahuchi	0.7	1.37	11.0
Dachahu	3.4	0.69	17.0

[a] *Chl a* is concentration of chlorophyll *a*. [b] SD is Secchi disk transparency. [c] TP is concentration of total phosphorus.

Table 2. Trophical status of the lakes of China

The lake	TSI(*Chl*)	TSI(SD)	TSI(TP)	TSI	Trophical status
Poyang	33.5	58.7	70.1	54.1	eutrophic
Dongting	25.6	63.2	73.1	54.0	eutrophic
Taihu	68.4	63.2	61.1	64.2	eutrophic
Hongze	42.6	82.8	75.4	66.9	eutrophic
Chaohu	57.2	82.8	71.3	70.4	hyperevtrophic
Tianezhou	41.7	66.5	49.4	52.5	eutrophic
Zhangdu	43.7	62.3	59.4	55.1	eutrophic
Moshui	73.8	75.7	109.1	86.2	hyperevtrophic
Longyang	74.2	70.4	103.1	82.6	hyperevtrophic
Sanjiao	73.0	63.7	87.6	74.8	hyperevtrophic
Dongdongt	42.0	64.1	60.6	55.6	eutrophic
Laojiang	56.4	65.9	67.3	63.2	eutrophic
Shijiu	48.7	59.4	64.6	57.6	eutrophic
Niushan	41.0	46.5	58.7	48.7	mesotrophic
Longgan	28.4	69.8	60.3	52.8	eutrophic
Junshan	33.2	49.0	54.1	45.4	mesotrophic
Sanligi	67.1	69.5	78.7	71.8	hyperevtrophic
Qingling	79.5	71.0	82.6	77.7	hyperevtrophic
Nanhu	78.1	75.7	87.9	80.6	hyperevtrophic
Dianshan	58.5	69.5	84.1	70.7	hyperevtrophic
Hongxing	72.9	69.2	83.7	75.3	hyperevtrophic
Huama	59.5	65.0	63.9	62.8	eutrophic
Wuchang	49.8	61.3	63.7	58.3	eutrophic
Yangcheng	58.2	63.7	71.7	64.5	eutrophic
Gehu	67.1	70.7	83.7	73.8	hyperevtrophic
Honghu	68.3	57.0	66.4	63.9	eutrophic
Baoan	63.5	57.0	69.8	63.4	eutrophic
Houguan	59.0	56.6	63.4	59.7	eutrophic
Banghu	33.2	58.0	34.1	41.8	mesotrophic
Dahuchi	27.1	55.5	38.7	40.4	mesotrophic
Dachahu	42.6	65.2	45.0	50.9	eutrophic

The study consists of three phases. First, the distribution of Chinese lakes was assessed according to the categories of trophic status. As an indicator of trophic status the Secchi disk visibility depth was used (SD). In this case, according to [4], the averaged Secchi disk visibility depth corresponds to ultraoligotrophic trophic status ≥ 12.0 M, to oligotrophic status > 6 m, to mesotrophic status 6.3 m, to eutrophic status 3–1.5 m, and to hypertrophic status is <1.5 m.

The results of the data analysis for 164 lakes in China show that 69.5% of the lakes are characterized as hypertrophic ones, 18.9% are eutrophic, 4.9% are mesotrophic, 4.9% are oligotrophic and 1.8% are ultraoligotrophic.

Secondly, the data for thirty one lakes of China (Table 1) was analyzed. As it follows from the above given data, 29 lakes examined by the magnitude of the visible disk Secchi are characterized as hypertrophic ones (SD <1.5 m) and 2 lakes (Niushan and Junshan) are characterized as eutrophic ones.

Along with the above mentioned, the Carlson's index was used to assess the trophic status of the lakes [5]. This index represents the average (TSI) of the three indices, taking into account the content of chlorophyll *a* TSI (*Chl*), Secchi disk visibility depth TSI (*SD*) and total phosphorus content TSI (*TP*). Calculations of indices are made using the formulas:

$$TSI\ (Chl) = 30.6\ 9.81 \cdot In\ [Chl] \quad (1)$$

$$TSI\ (SD) = 60 - 14.14 \cdot In\ [SD] \quad (2)$$

$$TSI\ (TP) = 4.15\ 14.42 \cdot In\ [TP] \quad (3)$$

According to Carlson‘s scale the oligotrophic status corresponds to the value of TSI <30, mesotrophic corresponds to TSI = 40–50, eutrophic corresponds to TSI variation interval from 50 to 70, and hypertrophic corresponds to 70 and more. Four lakes among examined 31 ones are characterized as mesotrophic (12.9%), 17 lakes are eutrophic (54.8%) and 10 lakes are hypertrophic (32.3%).

The results of calculations and evaluation of trophic status are shown in Table. 2.

Thirdly, the values of the critical phosphorus loadings in five largest lakes were assessed. The study of a trophic level of the reservoir depending on the amount of phosphorus input led to the development of so-called load concept, which is based on the concept of the existence of the quantitative relationship between the amount of phosphorus and the response of the reservoir. This usually results in a change of the position of the reservoir on the trophic scale. The first approximation value of phosphorus loading (L_{KP}, g P m^{-2} year^{-1}) proposed by Follenvider [6], making a reservoir possible to remain in the oligotrophic status, an average depth of the reservoir (D_{av}, m) was used as the only standard parameter [7]:

$$L_{Kp} = 0.025 \cdot D_{av}^{0.6} \quad (4)$$

The results of calculations by formula (4) are shown in Table. 3.

As it follows from (4), to calculate the critical phosphorus loading for a lake, the data on the average depth of a reservoir is required (D_{av}). However, the data for the most lakes in China are not available. To partially fill the gap and in a first approximation a quantitative relationship between the average depth of 141 lakes of China and a maximum depth (D_{max}) was found. The dependence is described by the following formula:

Table 3. Values of critical phosphorus loading for 5 largest lakes of China

The lake	Average depth, D_{av}, m	Square of the lake, km^2	L_{KP}, g P m^{-2} year^{-1}	Critical loading, t year^{-1}
Poyang	8.4	3210	0.090	288
Dongting	6.7	2740	0.078	214
Taihu	1.9	2428	0.037	89
Hongze	1.8	1580	0.036	56
Chaohu	4.4	820	0.061	50

$$D_{av} = -0.0088\ 0.5723\ D_{max}, \tag{5}$$

where $N = 141$; $r = 0.98$; $r^2 = 0.96$; $\sigma_{Y(X)} = 2.64$; $F_P = 3820$; $F_T = 3.92$; $F_P/F_T = 974$.

N is number of observations, r is correlation coefficient (the tightness of relationships between variables), r^2 is coefficient of determination (proportion of explainable variation), $\sigma_{Y(X)}$ is standard error, the F_P is the estimated value of the criterion of Fisher, F_T is tabulated point of Fisher's criterion for the significance level of 95%.

It follows from the statistical characteristics that the mathematical model (5) is adequate, since $F_p > F_T$ and, in addition, it can be used to predict the value of the average depth of other lakes in the presence of data on their maximum depths, as the $F_P > 4F_T$ [8].

REFERENCES

1. Dmitriev, V.V. and Frumin, G.T., *Ekologicheskoye normirovanie i stabilnost prirodnych sistem* (Ecological Normalization and Stability of Native Systems*)*, SPb, RGGMU: St. Petersburg, 2004.
2. Xiangcan, J., Lakes in China, *Research of their Environment*, vol. 1, China Ocean Press, 1995.
3. Songbo, W., Ping, X., Shikai, W. and Haijun, W., *Hydrobiologia*, 2007, no. 575, p. 203.
4. Henderson-Sellers, A. and Marklend, H.R., *Umirauschiye ozera i kontrol antropogennoi evtrofii* (Dieing Lakes. Reasons and Control of Antropogenic Eutrophy*)*, L.: Gidrometeoisdat, 1990, 280.
5. Carlson, R.E., *Limnology and Oceanography*, 1977, no. 22, p. 361.
6. Vollenweider, R.A., *Tech. Rep. Organiz. Econom*., Cooper. Devel., 1968, vol. 27, p. 159.
7. Gusakov, B.L., in *Elementi krugovorota fosfora v vodoemach* (Elements of phosphorus rotation in water reservoirs" в водоемах», Eds. Petrova, N.A. and Gutelmacher, B.L., L.: Nauka, 1987, pp. 7–17.
8. Landau, M.A., *Molekularniye mechanismi deistvija fisiologicheski aktivnich soedinenii* (Molecular mechanisms od effect of phisological active compounds), M.: Nauka, 1981, pp. 164–165.