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QUANTITATIVE CHANGES OF WATER COMPOSITION IN LAKE PEIPSI-PIHKVA IN 1985—1989

Abstract. The distribution and variation of total phosphorus, total nitrogen, chlorophyll *a*, dichromate oxidizability, colour, transparency and pH in the surface waters of Lake Peipsi-Pihkva and its regions during 1985—1989 are discussed.

The water composition varies in time, but no one-directional changes were observed in water characteristics during the observation period. The general change of the parameters over the lake has some regularity. The content of total phosphorus, total nitrogen, chlorophyll *a*, and organic matter decrease from the south to the north. The trend of the water transparency is the opposite.

Key words: Lake, water, total phosphorus, total nitrogen, chlorophyll *a*, dichromate oxidizability, colour, transparency, pH, changes.

Lake Peipsi-Pihkva consists of three parts: Lake Peipsi (area 2680 km^2, maximum depth 12.9 m, mean depth 8 m), Lake Pihkva (710 km^2, prevalent depth 3—5 m), and Lake Lämmijärv connecting them (170 km^2; 15.3 m; prevalent depth 2—3 m). The greatest length of the lake is 143 km, the greatest width 48 km (ENE, 1974). The main inlets into the lake proceed via the Velikaya River from the south and the Suur Emajõgi from the west.

The chemical study of L. Peipsi-Pihkva conducted at the Laboratory of Chemical and Statistical Analysis of the Institute of Zoology and Botany of the Estonian Academy of Sciences covers the period 1985—1989 from May to September. The concentration of total phosphorus (TP), total nitrogen (TN), and chlorophyll *a* (Chl *a*) as well as dichromate oxidizability (C), colour (Col), transparency (SD), and pH of water were determined.

Recently (Starast et al., 1988) it was established that L. Peipsi is a eutrophic lake. L. Lämmijärv is in a transition stage from the eutrophic state to the hypertrophic state. L. Pihkva is hypertrophic, its condition is catastrophic.

On the basis of the chemical composition data of the water L. Peipsi-Pihkva was divided using cluster analysis and expert estimation into seven regions (Möls et al., 1990). In this study the composition of the water in L. Peipsi-Pihkva and its regions during 1985—1989 (incl.) is discussed.

Material and Methods

Monthly field observations were carried out at 34 stations from May to September, 1985—1989. In 1989 there were only 12 sampling stations, in earlier years 29—34. The regions with their sampling stations in L. Peipsi-Pihkva are shown in Fig. 1. Water samples were collected at a depth of 0.5—1 m. References to the analysis technique have been presented earlier (Lindpere et al., 1988).

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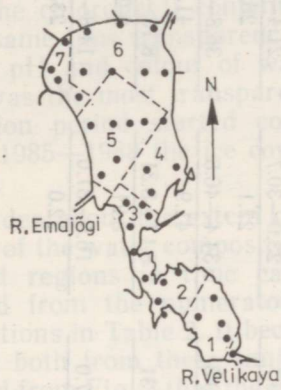

Fig. 1. L. Peipsi-Pihkva: L. Pihkva (regions 1 and 2), L. Lämmijärv (region 3), and L. Peipsi (regions 4 to 7). Sampling stations are denoted by dots.

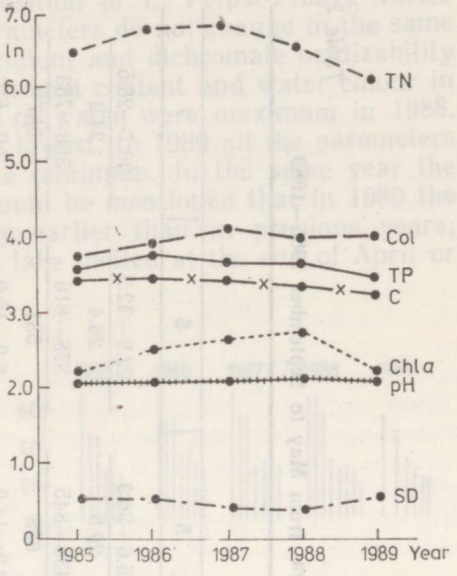

Fig. 2. Variation of the mean values (ln) of water composition from 1985 to 1989.

Table 1

Geometrical mean values of water composition of L. Peipsi-Pihkva from May to September 1985—1989

Parameter	Year					*V*
	1985	1986	1987	1988	1989	
TP, mg P/m³	35.0	43.2	39.4	39.7	31.9	11
TN, mg N/m³	646	869	942	730	455	26
Chl *a*, mg/m³	9.4	12.5	13.9	15.7	9.1	24
SD, m	1.68	1.73	1.54	1.50	1.78	7
C, mg O/l	30.1	32.4	32.1	29.7	25.8	9
pH	8.13	8.17	8.19	8.26	8.20	1
Col, °	43.9	51.5	61.5	52.9	54.4	12

All data were averaged to obtain the mean value for L. Peipsi-Pihkva (Table 1) and its regions (Table 2) in each year. The range given in Table 2 covers the minimum and maximum values of the five monthly averages concerned. The values in the denominator refer to the mean values over the years 1985—1989.

Results

In Table 1 and also in Fig. 2 the mean values (1985—1989) of total phosphorus, total nitrogen and chlorophyll *a* concentrations, transparency of water, dichromate oxidizability, colour and pH of L. Peipsi-Pihkva are given. Fig. 2 is drawn on the basis of the logarithmic data of Table 1. This procedure enables to compare the dynamics of all parameters under study on the same scale regardless of the unit.

Table 2

Geometrical mean values of water composition of different regions of L. Peipsi-Pihkva from May to September 1985—1989

Parameters	Regions, Min.-Max. / Mean						
	1	2	3	4	5	6	7
TP, mg P/m³	56.8—71.6 / 66.8	49.1—69.7 / 58.3	43.8—59.5 / 52.1	29.3—37.0 / 32.6	25.6—36.9 / 29.8	22.9—32.2 / 26.4	20.7—28.5 / 24.2
TN, mg N/m³	671—1154 / 935	771—1129 / 949	516—1281 / 938	504—890 / 731	436—845 / 628	378—816 / 581	308—753 / 557
Chl a, mg/m³	15.3—41.4 / 23.9	14.1—29.9 / 20.4	11.5—28.9 / 18.1	9.1—16.4 / 12.4	8.2—14.0 / 10.7	6.0—10.0 / 8.4	3.0—6.7 / 4.9
SD, m	0.96—1.22 / 1.06	0.97—1.36 / 1.17	1.06—1.29 / 1.20	1.52—1.82 / 1.70	1.81—2.26 / 2.06	2.00—2.40 / 2.17	2.36—2.97 / 2.70
C, mg O/l	32.5—39.5 / 36.4	31.9—34.9 / 34.1	28.7—35.0 / 32.5	26.8—31.8 / 29.3	23.9—30.7 / 27.6	23.0—30.7 / 27.1	21.4—29.4 / 26.3
Col, °	62.5—94.4 / 74.6	56.9—77.9 / 66.8	49.5—72.7 / 64.0	39.2—55.9 / 49.5	35.9—50.5 / 44.3	34.4—46.8 / 41.9	36.8—47.4 / 41.3
pH	8.06—8.38 / 8.21	8.04—8.30 / 8.12	8.09—8.24 / 8.15	8.10—8.30 / 8.19	8.19—8.31 / 8.23	8.17—8.31 / 8.21	8.18—8.21 / 8.20
N:P	11.8—16.7 / 14.0	11.4—19.6 / 16.3	11.2—23.2 / 18	15.3—29.8 / 22.4	17.0—27.0 / 21.1	16.5—31.0 / 22.0	14.8—27.5 / 23.0

It is evident that the water composition of L. Peipsi-Pihkva varies from year to year. The values of all parameters do not change in the same direction. Thus, the total phosphorus content and dichromate oxidizability were at maximum in 1986, the total nitrogen content and water colour in 1987. The chlorophyll content and pH of water were maximum in 1988. At the same time transparency was the lowest. In 1989 all the parameters (except pH and colour of water) were minimum. In the same year the water was the most transparent. It should be mentioned that in 1989 the vegetation period started considerably earlier than in previous years; during 1985—1988 the ice cover of the lake melted at the end of April or in May.

An idea about the extent of the change of the water composition in different regions in time can be obtained from the numerators of the fractions in Table 2. It becomes obvious both from these limit values and from Fig. 3 that the difference in the values of some parameters in different years is relatively small (pH of water, dichromate oxidizability) while in others it may be great. Most considerable variations occur in the total nitrogen (Table 1, $V=26$) and chlorophyll *a* content (Table 1, $V=24$). In most regions, for example, the difference in the limit values of chlorophyll *a* is more than twofold.

The water composition does not vary only in time but also along the lake, i. e. from region to region (Figs. 3, 4, 5, 6). It becomes obvious from the mean data of the water composition (denominator of the fraction in Table 2; Figs. 5, 6) of the vegetation periods (from May to September) of five years (1985—1989) that the water of L. Peipsi-Pihkva has the highest concentration of total phosphorus, chlorophyll *a*, and organic matter in the region nearest to the Velikaya River, i. e. in region 1. Since also the water colour (brownish-yellow) is the most intensive here, the transparency is the lowest. In this region, with its nutrient-rich water, the N:P ratio is the smallest. In the next two regions the contents of phosphorus, chlorophyll *a*, and organic matter decrease. The content of total nitrogen in these three regions, i. e. in L. Pihkva and L. Lämmijärv is nearly the same.

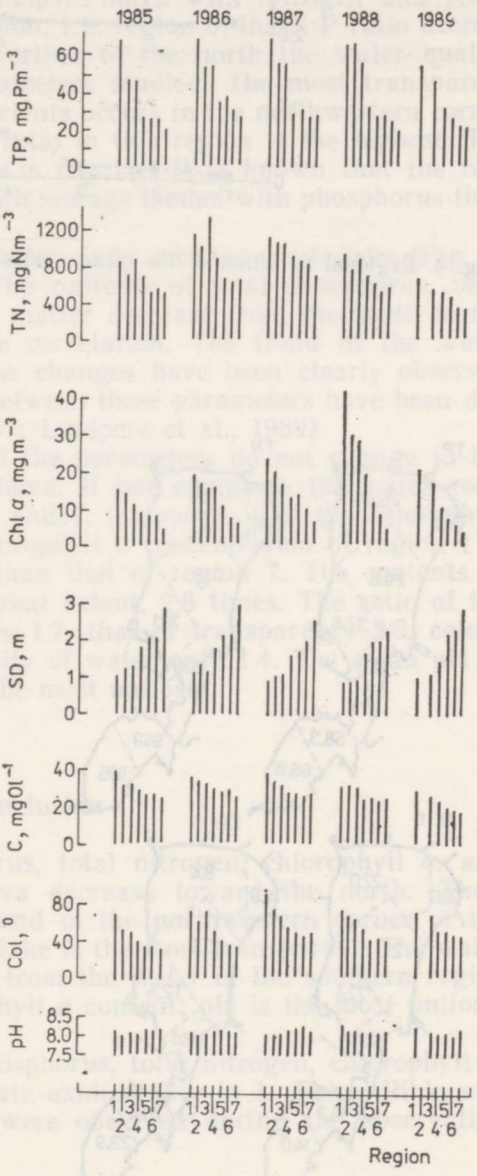

Fig. 3. Regional variation of water composition in different years.

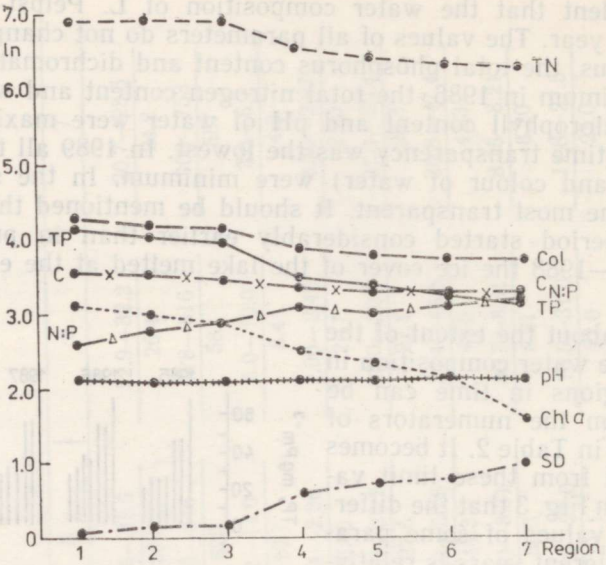

Fig. 4. Regional variation of the mean values (ln) of water composition in 1985—1989.

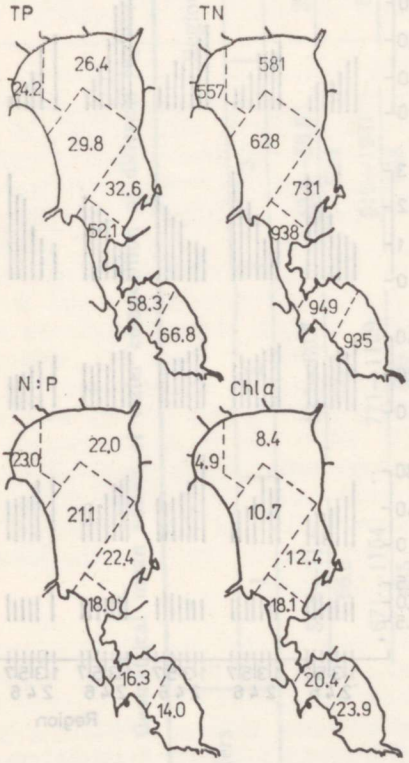

Fig. 5. Regional distribution of the mean values of TP (mg P/m³), TN (mg N/m³), N:P, and Chl *a* (mg/m³) in 1985—1989.

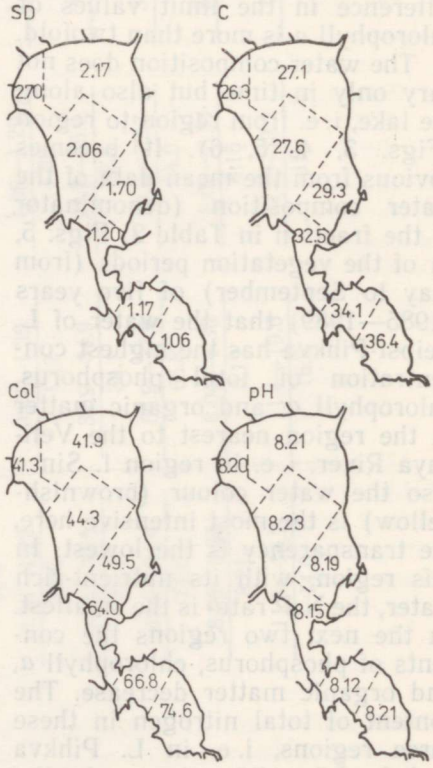

Fig. 6. Regional distribution of the mean values of SD (m), C (mg O/l), Col (°), and pH in 1985—1989.

A considerable dilution of water in the lake starts in L. Peipsi, i. e. in region 4 (Fig. 4). Although this region is affected by pollution from the Emajõgi River, the concentrations of total phosphorus, total nitrogen, chlorophyll *a*, and organic matter in the water are essentially lower than in L. Pihkva or L. Lämmijärv. The water is also more transparent, its colour being greenish-yellow. The N:P ratio undergoes an increase; this is caused by the inflow of the water from the Emajõgi which is rich in nitrogen compounds. The mean values were 1300 mg N/m^3 in the mouth of the Emajõgi River and 1040 mg N/m^3 in the mouth of the Velikaya River. The mean concentrations of total phosphorus were 78.4 mg P/m^3 and 74.4 mg P/m^3, respectively. Since the discharge of the Velikaya exceeds more than twice that of the Emajõgi, it should be considered the main source of pollution for L. Peipsi-Pihkva with nitrogen and phosphorus compounds. In the next region, i. e. region 5, the N:P ratio decreases and then starts increasing. Further to the north the water quality improves with respect to the parameters studied. The most transparent water with the least amount of nutrients occurs in the northwestern corner of the lake, in region 7. The N:P ratio in this region is the highest. The course of the change of this ratio is regular. It is known that the N:P ratio is lower in waters polluted with sewage loaded with phosphorus than in clean water.

The change of the parameters under study over the whole lake (Fig. 4) seems to have some regularity. The contents of total phosphorus, total nitrogen, chlorophyll, and organic matter decrease from the south to the north, i. e. they are in a positive correlation. The trend of the water transparency is the opposite. These changes have been clearly observed every year (Fig. 3). Correlations between these parameters have been discussed earlier (Старост et al., 1987; Lindpere et al., 1989).

It should be mentioned that all the parameters do not change to the same extent all over L. Peipsi-Pihkva. If one compares the water composition of the extreme regions, 1 and 7, it appears that the chlorophyll concentration varies most; the chlorophyll *a* concentration of region 1 is on the average 4.9 times higher than that of region 7. The contents of total phosphorus, too, vary to a great extent, 2.8 times. The ratio of the extreme values of total nitrogen is 1.7, that of transparency 2.5, colour 1.8, and the dichromatic oxidizability of water only 1.4. The mean pH of the water during the five years is the most uniform.

Conclusion

The contents of total phosphorus, total nitrogen, chlorophyll *a*, and organic matter in L. Peipsi-Pihkva decrease toward the north. Their smallest amount in water was found in the northwestern corner of the lake. The water in this part of the lake is the most transparent. The water of the northwestern corner differs from the water of the southern region mostly with respect to the chlorophyll *a* content; pH is the most uniform all over the lake.

As to the variation of total phosphorus, total nitrogen, chlorophyll *a*, transparency, colour, and dichromate oxidizability in L. Peipsi-Pihkva in time, no one-directional changes were observed during the observation period 1985—1989.

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