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Estimation of the Trophic Status of Selected Kazakhstan Lakes

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Abstract—The trophic status of seven Kazakhstan lakes has been estimated basing on the data on total phosphorus content in the water. The estimated trophic status varies widely, from the oligotrophic-mesotrophic to the eutrophic-hypereutrophic ones.

Keywords: Kazakhstan lakes, trophic status, morphometric parameters, total phosphorus, probability

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There are 48262 lakes located in Kazakhstan. 45248 of them are classified as small ones (less than 1 km^2); 296 lakes are larger than 10 km^2, and 21 are larger than 100 km^2. The latter group forms 60% of Kazakhstan lakes surface area. The diversity of landform and climate of Kazakhstan results in the non-uniform distribution of lakes: they are rare in the desert regions and more numerous in the Northern and mountain regions. The lakes can be either separated by hundreds of kilometers or form crowded lake systems, for instance, at the North of Kazakhstan [1]. Most of the lakes are located at 1400–2800 m height, the lakes number being much less below and above the mentioned limits. At below 1400 m, the significant aqueous erosion prevents formation of lakes. Many lakes (most of them being fresh) are found in the moistened regions; the lakes of arid climate regions are a few, being generally shallow, standing, salty, and drying in summer. For example, 740 lakes smaller than 1 km^2 are located in the forest-steppe region, the number of fresh and saltish ones being 6 times more than that of the salty ones. Fresh lakes become rarer and salty lakes become more numerous towards the South.

Shallow lakes are subject to strong anthropogenic eutrophication, a natural evolutionary process. Since the formation, a water reservoir generally undergoes several stages of evolution: from the ultraoligotrophic and oligotrophic early stages through the mesotrophic stage to eutrophic and hypertrophic late stages, the reservoir further developing into a bog. However, this natural process is affected by the anthropogenic factors;

Table 1. Geographical and morphometric parameters of the lakes

Lake	Coordinates	Surface area, km^2	Mean depth, m	The deepest point, m	Length, m	Width, m
Kopa	53°15'5" N, 69°44'32" E	13.80	2.6	3.50	5.35	3.60
Borovoe	53°04' N, 70°17' E	10.00	3.2	4.00	4.50	2.90
Bol'shoe Chebach'e	59°20'22" N, 78°56'14" E	21.61	8.3	31.60	1.50	1.40
Maloe Chebach'e	53°17' N, 69°87' E	19.80	6.3	10.93	7.90	2.60
Shchuch'e	52°59' N, 70°13' E	19.60	18.5	31.00	7.20	3.70
Maibalyk	53°15' N, 70°13' E	21.00	1.4	2.00	8.40	3.70
Zerenda	52°54′36"' N, 69°09'12.02" E	10.00	4.8	8.50	6.05	3.85

Table 2. Equations for calculation of probability of the trophic status of a reservoir from year-averaged total phosphorus concentration (TP, mg/m^3)

Trophic status	Equation
Ultraoligotrophic	$\mu(TP)_{UO} = 1 - \exp\{-\exp[-0.357(TP) + 1.25]\}$
Oligotrophic	$\mu(TP)_{O} = 0.66\exp\{-[-0.947\ln(TP/8)]^2\}$
Mesotrophic	$\mu(TP)_{M} = 0.66\exp\{-[-0.995\ln(TP/26)]^2\}$
Eutrophic	$\mu(TP)_{E} = 0.66\exp\{-[-0.964\ln(TP/89)]^2\}$
Hypertrophic	$\mu(TP)_{HT} = \exp\{-\exp[-0.0123(TP) + 1.65]\}$

Table 3. The OECD classification of trophic statuses

Total phosphorus concentration, mg/m^3	Trophic status
<4	Ultraoligotrophic
<10	Oligotrophic
10–35	Mesotrophic
35–100	Eutrophic
>100	Hypertrophic

Table 4. Probability of trophic status of the studied lakes from the total phosphorus concentration TP

Lake	Year	TP, mg/m^3	μ_{UO}	μ_{O}	μ_{M}	μ_{E}	μ_{HT}
Kopa	2004	92	0.00	0.00	0.14	0.66	0.20
	2005	44	0.00	0.05	0.50	0.42	0.03
	2008	26.8	0.00	0.17	0.65	0.16	0.02
	2009	36	0.00	0.08	0.59	0.30	0.03
	2010	57	0.00	0.02	0.36	0.55	0.07
	2011	77	0.00	0.01	0.21	0.65	0.13
	2012	69.5	0.00	0.01	0.25	0.63	0.11
Borovoe	2004	14	0.00	0.50	0.45	0.03	0.02
	2005	19	0.00	0.33	0.59	0.07	0.01
	2008	13.8	0.00	0.51	0.45	0.03	0.01
	2009	12	0.00	0.58	0.38	0.03	0.01
	2010	24	0.00	0.22	0.65	0.13	0.00
	2011	23	0.00	0.24	0.65	0.11	0.00
	2012	25	0.00	0.20	0.65	0.15	0.00
Bol'shoe Chebach'e	2008	8.8	0.14	0.65	0.20	0.00	0.01
	2009	10	0.09	0.63	0.26	0.01	0.01
	2010	21	0.00	0.27	0.63	0.09	0.01
	2011	19.8	0.00	0.31	0.61	0.08	0.00
	2012	21.5	0.00	0.27	0.63	0.10	0.00
Shchuch'e	2005	23	0.21	0.65	0.14	0.00	0.00
	2008	7.5	0.03	0.53	0.41	0.02	0.01
	2009	13	0.00	0.12	0.64	0.23	0.01
	2010	31	0.00	0.31	0.61	0.08	0.00
	2011	20	0.00	0.20	0.65	0.15	0.00

Table 4. (Contd.)

Lake	Year	TP, mg/m	μ_{UO}	μ_{O}	μ_{M}	μ_{E}	μ_{HT}
Maloe Chebach'e	2008	20	0.00	0.31	0.61	0.08	0.00
	2009	23	0.00	0.24	0.65	0.11	0.00
	2010	44.8	0.00	0.04	0.49	0.42	0.05
	2011	399	0.00	0.00	0.00	0.08	0.92
	2012	96.6	0.00	0.00	0.12	0.66	0.22
Maibalyk	2008	238	0.00	0.00	0.00	0.26	0.74
	2009	37	0.00	0.08	0.58	0.32	0.02
	2010	314	0.00	0.00	0.00	0.15	0.85
	2011	184	0.00	0.00	0.02	0.40	0.58
	2012	169	0.00	0.00	0.02	0.45	0.53
Zerenda	2011	33.5	0.00	0.09	0.61	0.27	0.03
	2012	38.5	0.00	0.07	0.56	0.34	0.03

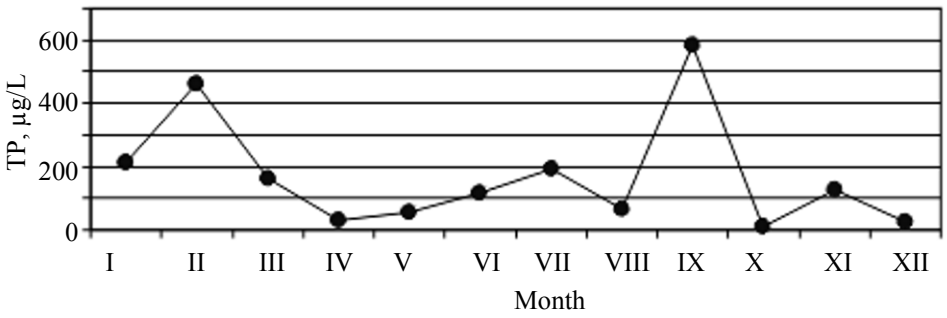
Table 5. Trophic status of the studied Kazakhstan lakes in 2012

Lake	μ_{UO}	μ_{O}	μ_{M}	μ_{E}	μ_{HT}	Trophic status
Kopa	0.00	0.01	0.25	0.62	0.12	Mesotrophic-eutrophic
Borovoe	0.00	0.20	0.65	0.14	0.01	Oligotrophic-mesotrophic
Bol'shoe Chebach'e	0.00	0.27	0.63	0.09	0.02	Oligotrophic-mesotrophic
Maloe Chebach'e	0.00	0.00	0.12	0.67	0.21	Hypertrophic-eutrophic
Shchuch'e	0.00	0.19	0.65	0.14	0.02	Oligotrophic-mesotrophic
Maibalyk	0.00	0.00	0.02	0.46	0.52	Eutrophic-hypertrophic
Zerenda	0.00	0.07	0.56	0.33	0.04	Eutrophic-mesotrophic

the rate of the ecological systems production being sharply increased. In particular, the natural eutrophication of a lake takes 1000 years or more, being accelerated by 2–3 orders of magnitude due to the anthropogenic factors [2].

EXPERIMENTAL

In this work we studied seven Kazakhstan lakes, their geographical location and parameters are given in Table 1.



Seasoned dynamics of total phosphorus concentration in the Maibalyk lake in 2012.

Table 6. OECD trophic status of the studied Kazakhstan lakes in 2012

Lake	TP, mg/m^3	Trophic status
Shchuch'e	20.0	Mesotrophic
Bol'shoe Chebach'e	21.5	Mesotrophic
Borovoe	25.0	Mesotrophic
Karasu	32.6	Mesotrophic
Zerenda	38.5	Eutrophic
Sultan Kel'dy	49.7	Eutrophic
Kopa	69.5	Eutrophic
Maloe Chebach'e	96.6	Eutrophic
Maibalyk	169	Hypertrophic

Raw data for the analysis were taken from the annual collections of chemical laboratory of Kazgidromet, part of Ministry of Ecology and Environmental Protection of Kazakhstan.

The lakes trophic status was estimated taking advantage of the earlier developed approach based on the total phosphorus content in water [3–7].

The trophicity status was graded in five levels reflecting probability of ultraoligotrophic (μ_{UO}), oligotrophic (μ_O), mesotrophic (μ_M), eutotrophic (μ_E), and hypertrophic (μ_{HT}) statuses.

The probability curves were analytically fitted [8] (Table 2) to facilitate precise estimation of the trophic status.

In all the cases the following condition was held:

$$\mu_{UO} + \mu_O + \mu_M + \mu_E + \mu_{HT} = 1 \text{ (or 100\%)}.$$

Another procedure to estimate the lake trophic status was based on the OECD classification (Table 3).

RESULTS AND DISCUSSION

The calculations results are given in Table 4.

The data in Table 5 demonstrates that the trophic status of the studied lakes was significantly different: oligotrophic-mesotrophic (the Borovoe, Bol'shoe Chebach'e, and Shchuch'e lakes) mesotrophic-eutrophic (the Kopa lake), eutrophic-mesotrophic (the Zerenda lake), hypertrophic-eutrophic (the Maloe Chebach'e lake), and eutrophic-hypertrophic (the Maibalyk lake). The latter lake revealed the highest trophic status in 2012, due to the high total phosphorus content (169 mg/m^3).

The seasoned dynamics of total phosphorus content in the Maibalyk lake is shown in the figure. The lowest total phosphorus concentration was observed in October (10 mg/m^3), being the highest in September (583 mg/m^3).

Table 6 gives the estimations of the studied Kazakhstan lakes based on the OECD classification; the total phosphorus concentration in 2012 was used for the estimation (except for the Shchuch'e lake, in that case data from 2011 were used). Four of the lakes were classified as mesotrophic, four lakes were considered eutrophic, and one of the lakes was hypertrophic.

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