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# Estimation of organic carbon stocks in bottom sediments of Middle Kaban lake (Kazan, Republic of Tatarstan)

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**Abstract.** The lakes has an enormous sediment carbon storage potential. This study aims to estimate sediment organic carbon stock in the of Middle Kaban lake, Republic of Tatarstan. The study revealed that the in the surface layer of lake sediments carbon stocks amount to 1134 tons. Total organic carbon stocks in the bottom sediments of Middle Kaban lake amount to 5986 tons. In CO2 equivalent, 21949 tons of greenhouse gases are accumulated in the lake bottom sediments.

## 1 Introduction

The Federal Law № 296-FZ dated July 2, 2021 "On Limiting Greenhouse Gas Emissions" aims to create conditions for sustainable and balanced development of the economy of the Russian Federation while reducing greenhouse gas emissions. In this regard, the problem of obtaining objective data on organic carbon stocks in various components of natural complexes, including aquatic ecosystems, is becoming increasingly relevant.

There are 14867 water bodies on the territory of the Republic of Tatarstan: 6914 rivers (5 km and longer), 6621 lakes, 1328 ponds and 4 reservoirs - Kuibyshev, Nizhnekamsk, Zainsk, Karabash [1]. All of them are accumulators of sediment, with organic matter of autochthonous (intra-watershed) and allochthonous (mainly soil) origin. In this connection, it is of undoubted interest to study the accumulation of organic matter (organic carbon) in the bottom sediments of water bodies and to assess their contribution to greenhouse gas emissions.

The purpose of this study was to assess the organic carbon stocks in the bottom sediments of Lake Middle Kaban, located in the central part of Kazan.

## 2 Materials and research methods

The choice of this particular water body is due to the good study of its bottom sediments, their thickness, chemical composition and properties, including the distribution of organic matter [2,3]. The water body is one of the largest lakes in the Republic of Tatarstan and the largest both in the Kaban lake system and in Kazan as a whole (table 1).

The lake is of old karst origin, and the main component of its water balance is underground sulfate-calcium water with mineralization of more than 1000 mg/l [4,5].

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Located in the urbanized area, the reservoir serves as a natural drain not only for natural surface and ground waters, but also as a receiver of various anthropogenic effluents. The lake has been experiencing a powerful anthropogenic load for more than 150 years by receiving wastewater from the city enterprises, historically located on its shores [6,7]. At the same time, the greatest contribution to water pollution of lake is made by the system of storm water drainage, which is not equipped with an elementary system of treatment facilities (settling tanks), which, at least, could capture suspended particles of soil, soil and urban dust washed from the city territory, containing huge amounts of pollutants deposited from the atmosphere on the city streets, oil products from leaks of motor vehicles. Thus, the sedimentation balance of the lake, including the organic matter balance, is formed by autochthonous (natural) and allochthonous (mainly anthropogenic) sources.

**Table 1.** Morphometric characteristics of lakes in the Kaban system in Kazan city [8].

| Lake | Area, hectare | Length, km | Width average, m | Depth, m | | Volume, thousand $m^3$ |
|---|---|---|---|---|---|---|
| | | | | middle | max | |
| Upper Kaban | 24.1 | 1.0 | 241 | 6.4 | 13.2 | 1544.9 |
| Middle Kaban | 131.3 | 3.7 | 346 | 7.8 | 19.0 | 10013.4 |
| Lower Kaban | 45.6 | 1.8 | 254 | 8.4 | 17.3 | 3820.9 |

To calculate the indicators of organic carbon accumulation in lake sediments, data on the values of loss on ignition in 88 samples of bottom sediments obtained from the results of the groundwater survey of the lake were used. They characterize the organic matter content along the bottom sediment profile layer by layer (with multiplicity of 10-20 cm) up to the depth of 110 cm.

It is considered that the organic matter content (%) in bottom sediments of different types of water bodies (lakes and reservoirs) is on average about 50% of the value of loss on ignition (%) [2]:

$$\text{Organic matter} = 0.5 \times \text{loss on ignition} \quad (1).$$

Natural organic compounds present in soils and bottom sediments contain 58% organic carbon [6], so a factor of 0.58 was used to calculate the proportion of the element in the total mass of organic matter.

Thus, the conversion formula for determining the share of organic carbon in the composition of lake bottom sediments can be presented as follows:

$$\text{Organic carbon (\%)} = 0.5 \times PPP \times 0.58 = 0.29 \times PPP \quad (2).$$

The carbon stocks in the DO of the lake within the selected areas of the bed with different sediment thickness (Wc, t) were calculated taking into account its actual content (Sorg, %) and sediment mass (m, t):

$$Wc = Sorg \times m / 100 \quad (3).$$

The mass of sediments (m, t) per unit area of the bottom (S, m2) was determined taking into account the natural density of sediments (P, t/m3) and their characteristic thickness (H, m):

$$m = S \times P \times H \quad (4)$$

Carbon stocks in sediments, were converted to organic carbon units using the formula:

$$\text{Organic carbon(t)} = Wc \times 3.6667 \quad (5)$$

## 3 The results of the study and their discussion

Modern bottom lakes are represented by black organic silts, which are characterized by low, atypical for the lakes of the Republic of Tatarstan, density of 0.2-0.4 g/cm3. The layers of sediment and bedrock below, forming the lake bed, have density 0.6-1.3 g/cm3 and higher [2]. Black coloration of silts is caused by accumulation of organic matter of different nature, including hydrocarbons (oil products). Thus, the content of oil products in the surface (0-10 cm) layer of lake bottom sediments reaches 1800-8800 mg/kg, which is 10-50 times higher than the regional background (according to Regional norms "Background content of oil products in bottom sediments of surface water bodies of the Republic of Tatarstan" (2020)).

The thickness of modern lake sediments varies from 5 to 95 cm and averages 42 cm. Sediments with thickness of 40-60 cm dominate in their structure (Fig. 1). The sedimentation rate in the lake is estimated to be 10 mm/year for the deep bottom areas and 5 mm/year on average for the lake [2].

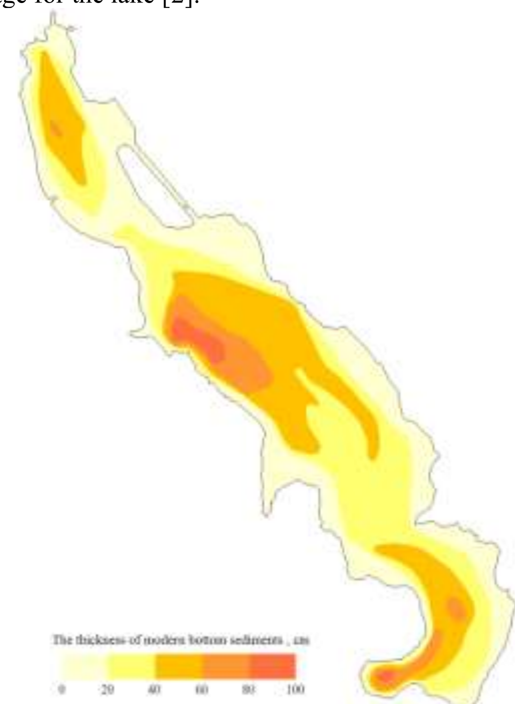


**Fig.1.** Map-scheme of the thickness of bottom sediments of Middle Kaban lake

The average organic matter content, determined by the value of mass loss during calcination, in the meter layer of lake bottom sediments is 11.8% with a variation from 2.3 to 74.3%. Vertical profile of bottom sediments the value of loss on ignition does not show significant variations, indicating the uniform character of the input and accumulation of allochthonous and autochthonous organic material in the lake bed in the temporal dynamics.

Practically complete absence of oxygen and high concentrations of hydrogen sulfide at the bottom of the deepest parts of the lake water area [4] ensure the processes of anaerobic destruction of organic matter deposited here. Redox conditions promote the processes of methane formation and emission of CH4 from lake sediments into water. In oxidizing conditions the organic matter of sediments undergoes microbial destruction with formation of carbon dioxide.

The sample of organic matter content (by loss on ignition) in lake sediments was ranked in order of increasing values (Fig. 2).

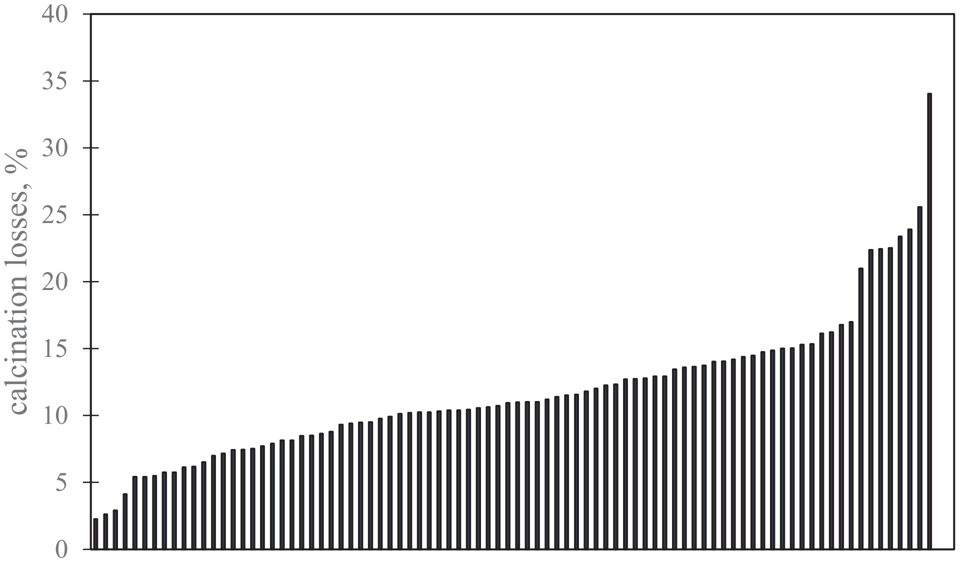


**Fig.2.** Histogram of distribution of values of calcination losses in bottom sediments of Middle Kaban lake

Figure 2 clearly shows that the distribution of calcination losses in lake bottom sediments is characterized by uniformity, with sediments with calcination losses ranging from 8 to 15% dominating. This is also confirmed by the results of statistical processing of the data (table 2).

**Table 2.** Indicators of variability of organic matter content in bottom sediments of Middle Kaban lake (n=88)

| Indicators | M | Me | Min | Max |
|---|---|---|---|---|
| Calcination losses, % | 11.8 | 11.0 | 2.3 | 34.0 |
| Organic matter, % | 6.5 | 6.0 | 1.2 | 18.7 |
| Organic carbon, % | 3.4 | 3.2 | 0.7 | 9.9 |

To calculate the indicators of organic carbon accumulation in the bottom sediments of Lake Middle Kaban, we took median values of organic carbon (table 2).

The lake bottom areas characterized by a certain thickness of bottom sediments were calculated taking into account the data shown in Figure 2.

Carbon stocks were calculated by formula (3), sediment mass - by formula (4). The average density of sediments P = 0.46 t/m3 (for sediments of the current year P = 0.27 t/m3). The results of calculation are given in Table 3.

Thus, the total organic carbon stock in the bottom sediments of Lake Sredny Kaban is about 6000 tons. Approximately one third of the reserves are concentrated in those areas of the bottom where the thickness of silt reaches 40-60 cm.

In CO2 equivalent, 21949 tons of greenhouse gases were accumulated in the bottom sediments of Lake Middle Kaban.

**Table 3.** Calculations of organic carbon stocks in sediments of Middle Kaban lake

| Average thickness of bottom sediments, м | Area of the bottom, m² | Weight sludge, t | Carbon stocks ($C_{opr}$), tons |
|---|---|---|---|
| 0.1 | 483080 | 22222 | 711 |
| 0.3 | 403307 | 55656 | 1781 |
| 0.5 | 326606 | 75119 | 2404 |
| 0.7 | 80265 | 25845 | 827 |
| 0.9 | 19852 | 8219 | 263 |
| TOTAL | 1313109 | 187061 | 5986 |

## 4 Conclusion

Thus, in eutrophic Middle Kaban lake the average organic carbon content is 3.2% with a variation of 0.7-9.9%. Depending on the thickness of bottom sediments in different parts of the bed, organic carbon stocks in them vary from 263 t to 2404 t. In the surface (0-10 cm) layer of the lake sediments, the carbon stocks amount to 1134 t. Total organic carbon stocks in the bottom sediments of Lake Kaban amount to 5986 tons. In CO2 equivalent, 21949 tons of greenhouse gases are accumulated in the bottom sediments of the lake.

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