INTRODUCTION

Lakes, as well as other landscape elements, participate in the evolution of the geographic envelope of the Earth. In their development, they pass through a series of stages of lake type proper, then turning into a new landscape structure. They are accumulating landscape elements in the continental runoff system. The most complex component of lacustrine accumulation, reflecting the specific features of ecosystem energy balance, is organic matter (OM) accumulation. The relationships between the rates of its accumulation, transformation in numerous cycles of lacustrine processes, and mineralization determined the evolution rate of the lake system [24, 25].

The original concept of water body evolution with the isolation of “oligotrophic” and “eutrophic” stages was later supplemented by a variant of “distrophic” with respect to lakes rich in allochthonous components of organic matter dissolved in water [53]. Ranging the lakes in accordance with the amount and origin of dissolved organic carbon (DOC) in water has resulted in the identification of the types of “allochthonous” lakes, which receive OM mostly from their watershed, and “autochthonous” lakes, which form this pool by processes within the water body [37, 50].

W. Rodhe [50] formalized the concept, arranging the lakes by the source and amount of DOC along two axes: from oligotrophic to eutrophic (autotrophy) and from oligotrophic to distrophic (allochrophy). These classifications came out of view in the 1970s when a close relationship was found to exist between the P load and the autochthonous primary production, a fact that was of importance for solving the main problem of that time—anthropogenic eutrophication of lakes. At the same time, studies of different types of lakes in the context of increasing anthropogenic impact, which were carried out under national and international programs, facilitated the development of modern limnology. The role of DOC in ecosystem processes was studied in greater detail [41, 44, 48, 51, 55, 56]. Particular attention was paid to the problem of different transformation paths of the autochthonous and allochthonous components of DOC pool in lake ecosystems.

The role of autochthonous (primary production) and allochthonous (input from the watershed) OM is different in different types of lakes. According to the general notion of C cycle in aquatic ecosystems, photosynthesis production, limited by biogenic elements, forms a pool of fixed autochthonous C in the euphotic (best illuminated) zone. The majority of this OM is involved in turnover here, while its lesser portion is mineralized in the deep-water mass or bottom sediments (BS). In low-productivity oligotrophic lakes, the input of allochthonous OM often predominates, especially when tributary waters are highly humified. Although it is believed that only 1–10% of allochthonous OM can be utilized and decomposed by bacteria, there is much evidence that it participates and even dominates in C biological cycles in humid lakes. In the opinion of many authors, bacterial utilization of DOC should be considered separately as energy mobilization from an external source (by analogy with photosynthesis) [41–43]. Therefore, energy mobilization in
pelagic food chains is simultaneously based on the light energy and the considerable chemically bounded energy of allochthonous OM. The value of heterotrophic energy increases with increasing allochthonous input of C. Bacterial mobilization often prevails, exceeding the primary production not only in considerably dyed, but also in transparent ultraoligotrophic lakes [45]. The pelagic systems with bacteria domination (heterotrophic) are supposed to be less effective in energy mobilization and biomass production than autotrophic systems. Bacteria contain about 10 times more P per C unit than phytoplankton (32 µg P/µg C and 3.8 µg P/µg C, respectively). This difference becomes critical when mineral P limits the production of both phytoplankton and bacteria [54]. Under certain conditions, bacteria can also suffer from the deficiency of available C forms [38, 39]. In some cases, bacteria cannot successfully compete with algae, losing, for example, when algae are optimally supplied with key chemical elements, such as Si and Fe for diatoms [54].

The undoubtedly large role of allochthonous C has been shown in experimental studies of bacterial degradation of humic complexes and in surveys of lakes. Studies of DOC mineralization in the large humified Lake Ortrasket (Northern Sweden) with the maximal depth of 64 m have shown the mean mineralization rate of Ctot in the summer to be 0.3 g C m–2 day–1 and to be almost equally distributed between the water mass and sediments. Ctot in water mass was mineralized by bacteria (60%), protozoan and metazoan plankton (30%) and in the process of chemical oxidation (10%). The primary production accounted for ~5% of the total Corg in the lake and ~20% of mineralized Corg. The isotopic composition of DOC and C of particulate matter confirmed the prevailing effect of soil OM input on the cycles of both organic and inorganic C in the lake [44].

The participation of a large amount of allochthonous component results in that OM destruction is far in excess of the total primary production, i.e., the system becomes heterotrophic. In the authors’ opinion, the relative contribution of the heterotrophic component to C cycle can serve as an estimate of lake trophic status [44]. Multidisciplinary studies of Lake Ladoga in 1975–2007 allow the researchers to identify the characteristic features of ecosystem transformation both in the period of critical P load and when it returns into admissible ranges [2, 16, 20]. The difference between these stages should be considered typologically significant for the assessment of lake trophic status and predicting its future evolution [11, 13].

**MATERIALS AND METHODS**

Lake Ladoga, located between 59°54′N and 61°47′N is among the northernmost great lakes in the World. This is a terminal water body of a huge water system, including lakes Onega, Il′men, and Saima.