The peculiarity of small lakes formation in the urban territory of Kazan, Russia

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Abstract. An analysis was made for the origin of 190 small lakes in the territory of Kazan, Russia. The obtained data made it possible to identify the main mechanisms for the formation of small lakes. Eight factors determining the formation of lakes were identified: seven natural factors and human impact. The natural factors of lakes formation are precipitation, air temperature fluctuations, wind influence, mineral composition, water runoff influence, groundwater, water currents and waves. These factors are responsible for five processes: human activity, fluvial, suffusion, karst erosion, and aeolian processes. These processes through seven mechanisms form different types of lake origin in the territory of Kazan.

1. Introduction

Nowadays, the task of revealing the regularities of the lakes formation depending on the landscape conditions, as well as the problems of the development of water ecosystems under the influence of human impact acquires great scientific importance. Human impact is expressed in the chemical pollution of lakes by substances such as heavy metals [1, 2], organic [3, 4] and oil products [5, 6]. But its influence also express in changing of morphometric parameters of lakes [7], which determining their influence to urban ecosystems [8] and the opportunity for using this lakes for recreation [9]. There are many publications about city lake restoration and water quality management [10, 11, 12], however for this we should have the knowledge about evolution of lakes, which include information about origin and transformation of lake basin.

The account of external factors of lakes formation allows to estimate their current state reasonably and predict the course of their further evolution taking into account changes in external conditions and processes occurring in the lake itself. At present, there is much experience in the study of large lakes, their basic morphometric and ecological characteristics have been established [13]. However, the data of small lakes (with an area of 1-10 km²) is still insufficient, due to the large number of lakes and variety of their characteristics.

We analyzed the origin of 190 lakes in the territory of Kazan. All investigated lakes are in the catchment basin of the Volga River, and are small shallow lakes (up to 1 km² and maximum depths of up to 2 m). In this work we used our own regional classification of lakes origin. The obtained data make it possible to present the evolution of Lake Morpholitogenesis in the following form: conditions - factors - processes - mechanism of formation of lake basins - genetic types of lakes.

The main concepts of Lake Morpholitogenesis, first of all, include the concept of "process", which determines the successive change of states and natural links of following one after another stages of evolution of Lake Morpholitigenesis. Concept “factor” is understood in this instance as propulsion of
making process or one of necessary conditions. Concept “mechanism” determines sequence and interaction of processes and events, which conditioning the direction of process (result of action). At the same time we used the assumption that the lake formation in the territory of Kazan occurs in the relatively stable natural conditions of the plain on the Middle Volga, when morpholithological, climatic and anthropogenic conditions have become the main conditions, because their variations cause a significant change in the processes lake basins formation, intensity of sedimentation and the degradation of the lake.

2. Factors in the lakes formation on the territory of Kazan city

For the Kazan area, we identified five processes that determine the lake basin formation: anthropogenic process, suffusion, karst, fluvial, and aeolian (figure 1). These processes are caused by 8 factors: anthropogenic factor, which can both form new lakes and modify existing [14, 15] and 7 factors which have natural origin. Three of the factors are climatic: atmospheric precipitation, air temperature, and wind, which affects both evaporation and detalization of coastline.

![Figure 1. The structural-functional scheme of the lake hollows formation in the Kazan City.](image)

Other factors are geological and hydrogeological: the composition of rocks and groundwater, the impact of surface water, this should include impact of water flow and formation of proluvial deposits.

For example, the Basin of Bolshoe Glubokoe Lake and Maloe Glubokoe Lake, according to the old maps were a single lake, which was divided by the alluvial cone of a large ravine. Currently in the north-western coast of Bolshoe Glubokoe lake is the beach, formed by alluvial cone of several ravines. According to our data, during 10 years in the northwestern coast of the lake the coastline has receded.
by more than 7 m. The presence of the above processes allows us to identify 6 mechanisms for the lake basin formation in the territory of Kazan.

The anthropogenic impact mechanism is expressed both in the formation of basin and in raising the level of groundwater. Due to aeolian processes, the impact of the deflation and redeposition mechanisms is the cause of dune lakes formation. According to one of the hypotheses, Lebyazhye lake system was formed in this way. As a result of mechanisms of meandering and the drying up of watercourses, were formed the bayou and deltaic lakes.

Karst processes by dissolving rocks and forming cavities form karst funnels in which karst lakes are formed. In compaction and dissolution processes, as a result of the compaction of rocks, suffusion lakes are formed. On the territory of Kazan often occurs the result of combined processes: suffusion-karst lakes.

3. The development of lakes on the territory of Kazan city
After the formation, lakes are developing, changing their size and physico-chemical parameters of water. Eventually lakes are filling with sediment, overgrown and dries. On the territory of Kazan we found out the examples both of gradually or sudden changes of lakes condition. The results of the analysis of this process is shown in figure 2.

In the transgression stage the lake's hollow is flooding (transgression), the water level and water volume in the lake is increasing, and the area and depth of the lake basin is increasing too.

For lakes of the Kazan city we found out note a strong anthropogenic influence, as about a third of the lakes in the city of Kazan have an artificial origin (54 lakes). The human activity can be expressed as an indirect influence on the course of natural processes and purposeful changes in the lake watershed.

*Indirect human* impact determines the mechanism of raising the level of ground water in hydraulic flooding due to changes in the level of the Kuybyshev reservoir because in the Kazan city groundwater usually is at a depth of 0.2-5 m. Due to hydraulic flooding, intensified fluvial processes have formed bayou and deltaic lakes. The increase of groundwater level and seasonal changes in the level of the Kuybyshev reservoir, undoubtedly, have an impact on the hydrological regime of lakes, especially during the spring floods, but this effect is not yet known.

One of the consequences of construction is underflooding causes the formation of lakes. For example, in the Novo-Savinovsky district of Kazan city, the construction in residential neighborhoods was the cause of formation of many lakes: Kroshka Lake, Ugolok Lake etc. Some kind of indirect human impacts (e.g., mining) determine the mechanism of the formation of basins with subsequent filling them with water (Emerald Lake near Yudino village formed on the site of a former sand quarry).

*Direct human* impact affects the processes of formation and development of lakes through the mechanism of the formation of the basins of artificial lakes due to dams construction (School Lake, Farmer Lake) or digging depressions (Central Lake in the Park of Victory). In addition, this mechanism can be expressed through the purification and aeration of water bodies overgrown (Large Chuikova Lake and Small Chuikova Lake, Nizhny Kaban Lake, Mar’ino Lake) which can be called the restored lakes.

*Natural processes* of formation of lakes on the territory of the Kazan city is represented by the following types. Karst processes through the mechanism of the collapse of vaults of caves lead to the formation of karst lakes (Large Glubokoe Lake). Suffusion processes due to the action of the compaction mechanism and erosion of rocks form the suffusion lakes (Chishmale Lake).

Despite the fact that the waves on the lakes of the Kazan city rarely exceed 0.3 m in height, their abrasive activity is of great importance in the formation of coastline. For example, the North-Western shore of the Central Lake in the Victory Park for two years has retreated by about 0.7 m.

You also need to consider the complexity of the process of formation and development of lakes, which proceeding with the participation of several mechanisms. For example, in the case of combined
effects of the mechanisms of the collapse of vaults of caves and compaction, erosion and dissolution of rocks are formed by suffusion-karst lakes (Krugloe Lake).

Figure 2. The structural-functional scheme of development of Lake Morpholithogenesis on the territory of Kazan City.

The regression stage of the lakes development is characterized by the degradation of lakes, as a result, the size of the lake basin and the volume of water mass is reduced and water quality deteriorates.

Features of sedimentation and eutrophication are determined by the peculiarities of the lake hollow, but in urban areas the special role played by the human factor.

The intensity of lakes degradation is different. The degradation rate depends primarily on the size of lakes; because of the greater volume of water mass and, consequently, the dissolving ability large lakes are degraded more slowly (in the Central part of the Kazan city remained only relatively large lakes). However, long-term chronic pollution in them is still there are irreversible changes (in the 1980 on the lakes Kaban had to carry out special cleaning events).

The evolutionary path of the regression stage involves reducing the volume of water mass and depth of the lake basin as a result of gradual accumulation of sediments and decreasing of an income part of water balance. It is associated with the degradation mechanisms of lakes: accumulation, eutrophication, drying-up, caused by both natural and anthropogenic processes.

4. Conclusion
Altogether, the study has shown that in the Kazan City the formation of lake hollows due to the 7 factors of natural origin (wind, water temperature, precipitation, water currents and waves, water runoff and sediment yield, underground water, and composition of rocks) and anthropogenic factor.
Anthropogenic process can be expressed as an indirect influence on the course of natural processes and targeted changes in the lake basin.

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