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The Influence of Anthropogenic Factors on the Ecological Status of the Spawning Grounds of Lake Senezh

Alexey L. Nikiforov-Nikishin [1], Mikhail V. Shatokhin [1], Andrey K. Ponomarev [1], Natalia A. Golovacheva [1], Alexey L. Borodin [1], Natalia A. Zaitseva [2,3], Anna A. Larionova [2,4*]

[1] K.G. Razumovsky Moscow State University of Technologies and Management (the First Cossack University), Moscow, RUSSIA

[2] Immanuel Kant Baltic Federal University, Kaliningrad, RUSSIA

[3] Plekhanov Russian University of Economics, Moscow, RUSSIA

[4] The Kosygin State University of Russia (Technology. Design. Art), Moscow, RUSSIA

[*] Corresponding author: annla@list.ru

Abstract

The relevance of the study of the influence of anthropogenic factors on the ecological state of artificial and natural water bodies is determined by the increasing level of pollution of lakes, reservoirs and ponds. The greatest negative load is noted in the territories adjacent to large megacities, including Moscow. The purpose of this study was to assess the effects of anthropogenic factors on the ecological status of the spawning grounds of Lake Senezh. The paper presents the results of a differentiated analysis of the hydrocarbon content in a rainfall runoff from Timonovsky Highway, washed away from the carriageway and dam to Lake Senezh. According to the results of the study, an assessment was made of the environmental consequences of mistakes in the design of roads surrounding Lake Senezh, the ratio of dissolved and undissolved parts of petroleum products sediment and crumb rubber, each of which harms developing fish eggs on spawning grounds and directly to higher aquatic plants, as a substrate for spawning grounds, assessment of the presence and state of plankton organisms in this lake has been carried out. Recommendations, the implementation of which is necessary to preserve natural spawning grounds, improve the conditions for the reproduction of fish and increase their reserves in Lake Senezh, were developed. The materials of the article will be useful for regional and federal authorities involved in the conservation of biological systems of artificial and natural water bodies. The described methods for assessing the impact of anthropogenic factors on the ecological status of the spawning grounds of the analyzed lake can be used when conducting similar studies in other regions.

Keywords: Lake Senezh, anthropogenic factors, ecological status, petroleum products, polycyclic hydrocarbons, benzopyrene, macrophytes, zoogles, spawning grounds

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INTRODUCTION

Lake Senezhsky is one of the most beautiful lakes and places for recreation in the Moscow region, which is located on the north of the city of Solnechnogorsk. Lake Senezhsky is located on the Klinsko-Dmitrovskaya ridge. The lake area is 8.51 km^2, the catchment area is 69.2 km^2, the maximum length is 5 km, and the width is up to 3.5 km. The greatest depth is 6 m (average — 2.5—3.5 m). The name of the reservoir comes from the name of a small lake of glacial origin, which today is a bay in its southern part and is called Old Senezh. Senezh Lake is an artificial flow pond into which the waters of the Sisters and Mazihi rivers flow, and the flow from the lake is blocked by a dam. Senezh is not a natural reservoir, but one of the oldest reservoirs near Moscow, which was formed in 1826, when a canal connecting the Istra and Sister rivers was being built. Work continued for about 25 years, during which three stone locks, a channel 8.5 km long and a dam were built. The rivers Sister and Istra were straightened. Thirteen wooden and stone locks of the same size as on the Tikhvin water system were built on the Istra river, and 13 on the Sestra river. A new waterway has become necessary in order to deliver the stone from which the builders subsequently erected the Cathedral of Christ

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the Savior from the Volga to Moscow faster and cheaper. The canal was being built for almost a quarter of a century, having built three stone locks, a dam and 8.5 km of the earthen channel. On old maps, the lake is also called Senezhskoe-Gushchino.

However, the artificial canal could not stand the competition with the built railway and as a result it turned out to be abandoned. At the end of the 19th century, the first hydroelectric power station near Moscow appeared on the dam of Lake Senezh. It was built with the help of Baron Knopp and had a power of 50 kW. In the middle of the last century in order tanks could move to the training ground passing by reservoir, old hydraulic engineering constructions were concreted, and a dam was filled up.

Today on the bank of the lake there is a city of Solnechnogorsk and also smaller settlements are located. The Sestra River flows from the reservoir, and several streams flow into it from the southern side.

METHODOLOGICAL FRAMEWORK

The main objective of this study was to conduct a differentiated analysis of the hydrocarbon content in the draft of the storm runoff from Timonovskoye Highway, washed away from the carriageway and dam. The peculiarity of this flow is that in this case we are dealing with a drain containing high concentrations of suspended hydrocarbon particles related to polar hydrocarbons: asphaltenes, crumb rubber, petroleum resins and naphthenic acids.

Oil products can be sorbed and dissolved in large quantities on all the above-mentioned particles. Consequently, suspended particles of polar hydrocarbons, with the content of oil particles in large quantities, fall into the water area of Lake Senezh, this property is typical for stormwater runoff from highways.

When determining the concentration of oil in the water of fishery bodies of water, it is customary to take into account usually dissolved and emulsified oil products, but not oil associated with hydrocarbon particles that not only adsorb oil products, but also swell from their presence. It is generally accepted that petroleum products are called non-polar hydrocarbons, soluble in hexane.

Currently, a number of techniques have been created for determining the concentration of oil in the water of water bodies: gravimetric determination, luminescent chromatographic, spectrophotometric in the IR spectrum.

Initially, both polar and non-polar compounds are dissolved by chloroform or carbon tetrachloride, then only non-polar compounds are separated and quantified by various methods (Cotton and Wilkinson 1988, Drugov and Rodin 2007, Eaton et al. 1995, Finochenko and Finochenko 2003, Golubeva 1964, 1966, Sawyer et al. 1994, Smith 1995, Smith 1997, Semenov et al. 1977, Stumm and Morgan 1996, Ulanova and Makarova 2010).

For storm water runoff from the road, when there is an assumption that there is a very high concentration of microscopic rubber crumb and asphaltenes, it is possible that the sample should be pre-cleaned from the suspension of these hydrocarbons. But for this it is needed to have an idea about the amount of suspended particles of hydrocarbons contained in the sediment storm drain from the road.

In current studies, it was necessary to identify the percentage of suspended hydrocarbon particles to the total volume of samples of precipitation of storm drains from the road. The national sample collected from Timonovskoye Highway over the 20 days of the summer of 2018 was investigated, which makes it possible to obtain integral results.

The basis of the applied method of computer and microscopic analysis is the ability of polar and non-polar hydrocarbons to be extracted with various solvents in microscopic preparations under direct microscopic control.

Microscopic preparations “pressure drop” were prepared for the study. The precipitate for microscopic examination was taken from the surface and from the middle of the vessel, which achieved its averaging. The cover glass practically made the sediment preparation minimal in height, which allowed the volume ratio of suspended hydrocarbons and the total sediment to be counted over an area within the field of view of the microscope.

After the light was established by Keller, a dried drop of sediment was placed in the field of view of the microscope under a cover glass. Under the cover glass, various compounds were injected with a syringe under constant microscopy of the preparation.

1. To identify all hydrocarbon compounds in the sediment - water was brought in.

2. For the extraction of non-polar compounds (petroleum) in a dried drop of sediment on a glass slide - hexane was brought in.

3. For dissolution of polar hydrocarbons (suspended particles), except rubber crumb - chloroform was used.

4. Under the influence of chloroform tire rubber particles (resistant to organic solvents) slowly dissolved and gave around the soot granules.

Thus, it was possible to conduct a differentiated qualitative analysis of the sediment of storm sewage from the highway to the distribution of petroleum products, asphaltenes and resins, as well as microscopic rubber tire crumbs.

Digital microphotography of each variant of the study was used to record the results. Preparations, approximately were selected for the density. For identification of each fraction of hydrocarbons three micromedicines were investigated. Further quantitative analysis carried out on a computer showed that the deviation from the average in each variation was no more than 2 – 3 %.

For computer quantitative analysis, a histogram was studied and the total area of black particles corresponding to asphaltenes and tire rubber containing a large amount of soot was measured.

RESULTS AND DISCUSSIONS

Assessment of the Environmental Consequences of Mistakes in the Design of Roads Surrounding Lake Senezh

The study of highways and junctions in the immediate vicinity of the lake allows concluding that there are design errors during the construction of roads, when the designers did not think about preserving the ecology of Solnechnogorsk, this water body and the anthropogenic load on Lake Senezh. So Timonovskoe highway goes on the very shore of the lake and essentially captures almost 1/3 of the shoreline of the lake, where the main natural spawning grounds are located.

Perhaps, before the growth of the village of Timonovo and the construction of a multitude of villas, this was a road that motor transport rarely took. At the present time it is a highway with a heavy traffic. According to the research results of the authors of the article in July 2018, the cars crossed a conditional lane on the road in the daytime every 5 to 10 seconds.

The highway is located very close to the lake, with the exception of a small area “Fisherman’s House” and “House of Artists”, thus all automobile gases and drains from the road get directly into the lake, causing the greatest harm to fish spawning grounds.

It is well known that 1 m^2 of a highway can contain up to 1 mg of 3,4-benzopyrene, which is a strong mutagen and carcinogen (Bourque et al. 2018, Haritash and Kaushik 2009, Li et al. 2018, Ugochukwu and Ochonogor 2018). On the developing caviar of fish, benzopyrene has a destructive effect and drastically reduces the release of fish from the eggs.

In addition to the suppression of fish embryonic development, automobile exhausts and runoff from the roadbed cause a reduction in the areas occupied by higher aquatic plants, reduce the area of spawning grounds and the biofiltration functions of macrophytes for the whole lake (Bryan and Langston 1992, Gan et al. 2009, Nash and Sutcliffe 1970).

Besides, drains after thawing of snow and after a rain can contain other dangerous soluble and insoluble hydrocarbons which do harm to spawning areas, first of all the fishes who are in an embryonic and larval state and the shipped water vegetation which is substrate for spawning (Lima and Reddy 2003, Srivastava et al. 2008, Wang et al. 2017, Yakovleva et al. 2008).

According to the study of the authors of an article conducted in the summer of 2018, the strip of submerged aquatic plants used by fish for laying eggs, has decreased over 5 years, compared to data obtained by researchers of the geographical faculty of Moscow State University, at the dam by 25 meters, and in the City Bay area 30 meters (Kuzmina and Sazonova 2014).

On the opposite birch, in the bay of the Sestra River, where also large areas are occupied by submerged aquatic plants and constitute also an important part of the spawning grounds of Lake Senezh, the flow of wastewater from petroleum products is possible, which also increases the anthropogenic load on the spawning grounds (Bychkova et al. 2017, Ershova et al. 2009).

Thus, the natural spawning grounds of Lake Senezh are in the tight grip of anthropogenic pollution, associated with the recent sharp increase in the number of vehicles engaged in heavy traffic along 2/3 of the lake’s water area, and first of all it is Timonovskoye Highway, which does not have any drainage system and ditch (Gorbunov et al. 2013, Kozlov and Ivanova 2013).

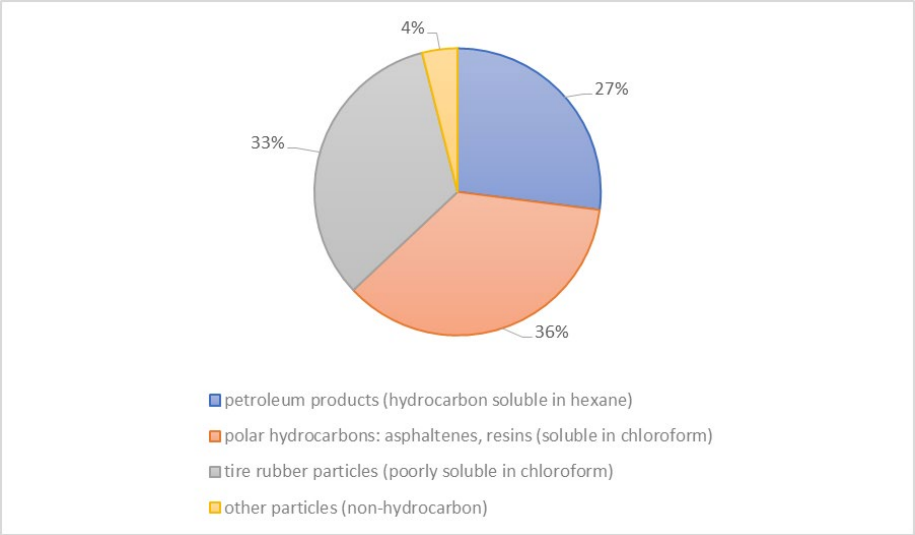

Fig. 1. Structure of heavy hydrocarbon fractions (black) contained in precipitation of storm runoff from Timonovsky Highway

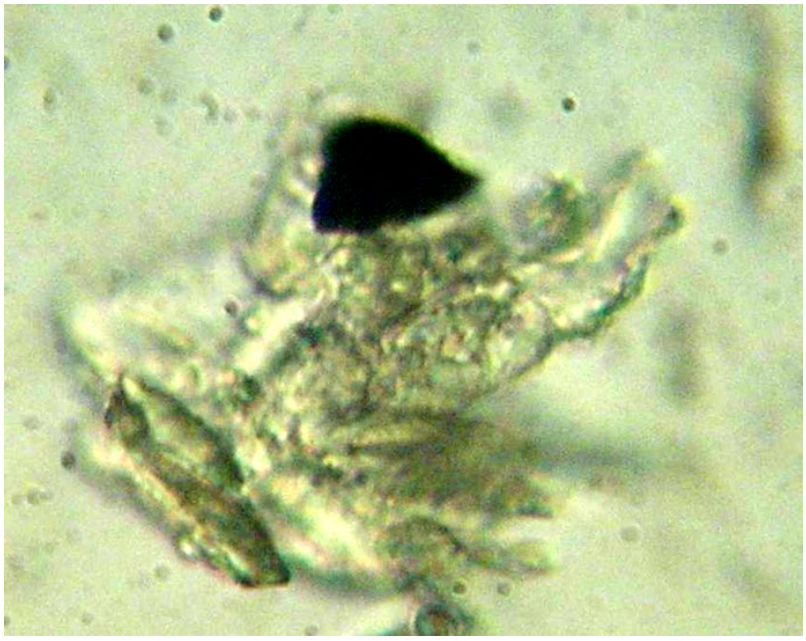

Fig. 2. Zoogles from the coastal zone of the lake with a rubber-like particle

To assess the impact of runoff from the Timonovskoe highway to spawning grounds and to identify fractions of oil products harmful to hydrobionts that fall into the coastal part of the lake, we carried out a microscopic and computer analysis of storm water sediment from the highway.

The Structure of Heavy Fractions of Hydrocarbons (Black) Contained in Precipitation of Storm Runoff

A microscopic and computer analysis of rainfall runoff from Timonovsky Highway showed that the total content of heavy hydrocarbon fractions (black) is about 55% of the total sediment. The structure of these fractions is shown in **Fig. 1**.

The study of water samples from the coastal areas of the lake showed that at the bottom there is a sediment of very small zoogles, the basis of which is Zooglearamigera.

In addition to mineral inclusions, black microscopic particles resembling rubber-like inclusions, which are often found in washes from concrete surfaces during heavy traffic, are encountered in zoogles, especially when braking motor vehicles. Most likely, these particles in the zoogles come from tires of vehicles. Zoogly with such a rubber-like particle is presented in **Fig. 2**.

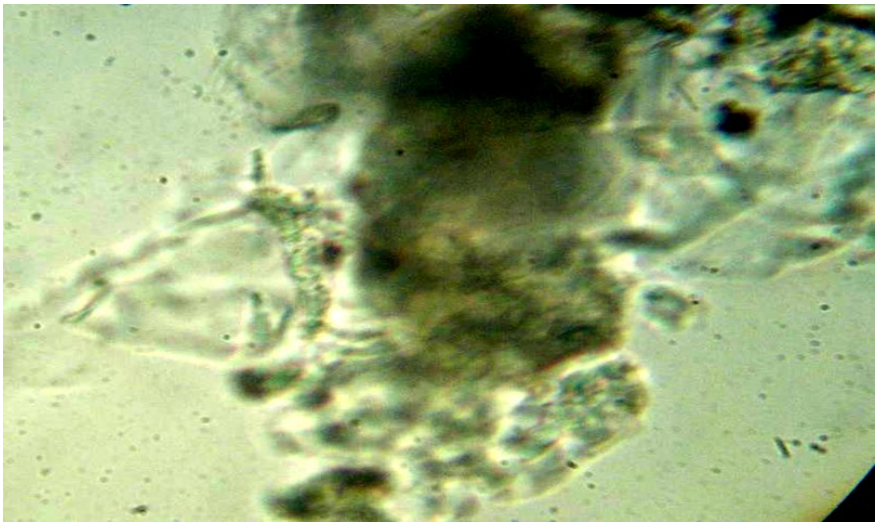

Fig. 3. Bacterial film with the inclusion of organic remains of plankton organisms in water samples

Fig. 4. Example of a surface film of petrochemical nature flowing from Timonovsky Highway to Senezh Lake

Such zoogles are often also found in the draft of the sample from the storm runoff from the highway (40 x 15).

The authors of the article studied zoobenthos and zooplankton in a sample of water from Lake Senezh. Representatives of zoobenthos were investigated in the sample sediment, and these are mainly very small zoogles and fine detritus (vegetable fibers) (Farkas et al. 2015).

The results of the study showed that in some cases a developed bacterial film is observed in detritus, which includes oil-like particles (black). A bacterial film of sludge from a lake with oil-like particles is shown in **Fig. 3**.

The same black particles, mainly asphaltenes and microscopic crumb rubber from car tires, are found on submerged aquatic vegetation (macrophytes). The hornberry, pulled ashore near the road close to the dam, has a grayish color of the leaves and due to the absorption of sediment on them, washed away in the carriageway of the roadway (**Fig. 4**).

A study of the lake's soil in the coastal areas of the spawning grounds in the area of the Artist's House, where the highway is located near, using a dredger, showed on July 16-17, 2018 that the soil has a black shade of oil, and under the microscope angular microscopic crumbs of rubber and oil-like particles are deposited at the bottom of the lake for several years. This again shows the damage that spawning grounds cause to the highway that runs along or across the lake.

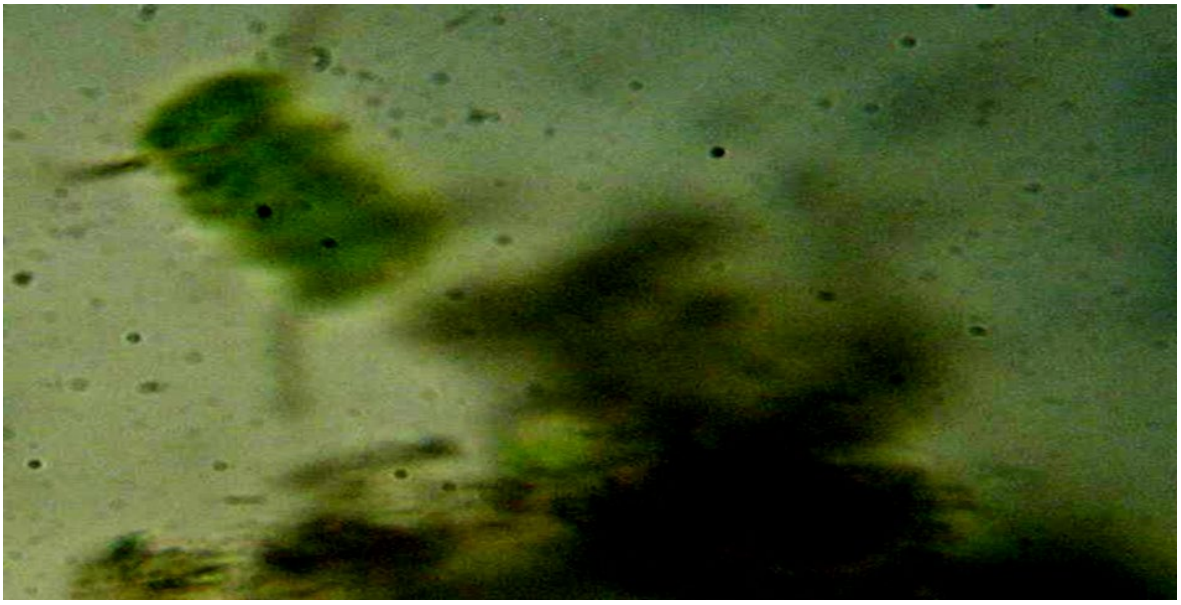

Fig. 5. Cells of cenobiascenedesmus that have Just started to destruct under the influence of runoff from the road, in which chlorophyll is still preserved

Assessment of the Presence and Condition of Plankton Organisms in Lake Senezh

The study of planktonic organisms shows that the development of phytoplankton and zooplankton in this water is sharply suppressed. Phytoplankton is represented by single colored flagellates, as well as chlorella autospores.

Among seaweed the considerable share was occupied by protokokkovy seaweed from which, besides a chlorella, it is possible to note existence of a stsenedesmus (Scenedesmusquadricauda). Individual specimens of these algae have survived until recently and died recently, as the cells in their cenobia have not yet lost chlorophyll, although the destruction of the outgrowths has already been noted. One such coenobia with destructed cells is presented in **Fig. 5**.

Among mixotrophic organisms in water samples taken close to the shore, there were various types of very small trachelo-monads, which are little sensitive to the increased toxicity of water and survive when mineral and organic pollutants are harmful to other organisms. In the test sample, there were no adult copepods, although some cyclop nauplii were encountered. The analysis indicates that the runoff from the road located on the shore of the lake, heavily pollutes the pond, and sediment particles (petroleum products, asphaltenes and crumb rubber) are deposited and inhibit the development of plankton and benthic organisms.

The remaining representatives of zooplankton organisms, characteristic of other parts of Lake Senezh, are strongly suppressed in coastal samples, which indicates unfavorable ecological conditions at spawning grounds created by the flow of storm water and melting snow from the road leading along the lake and the dam.

CONCLUSION

According to the results of a study conducted by the authors of the article, it was determined that after melting of snow and after rain there are hazardous soluble and insoluble hydrocarbons, which damage spawning grounds, primarily fish, in the embryonic and larval state and submerged aquatic vegetation, which is a substrate for spawning. The natural spawning grounds themselves, like the Lake Senezh itself, are under great negative anthropogenic pressure.

In order to preserve natural spawning grounds, improve the conditions for the reproduction of fish and increase their reserves, the following can be recommended:

1. To preserve coastal higher aquatic vegetation, including macrophytes submerged in water, on which fish lay eggs. It is possible to remove the submerged higher water vegetation partially only in those places where people bathe, or if it strongly interferes with watercrafts.

2. Timonovskoe highway should be closed to vehicles. A transport passage can be carried out on a parallel highway after connecting it with the road from Osipovo to the dam part of the Timonovskoe highway

(this will require the construction of 1-1.5 km of the road).

3. The territory, freed from the road, cannot be built up with summer residences and industrial enterprises. This should be an environmentally friendly water protection zone.

4. On the dam part of the road should be constructed sewage catchment ditches, which divert water from the entire dam part of the road to the gabion treatment plants with bioplato.

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