

## Article

# Anthropogenic Transformations in the Mouth Area of Tributaries as Factors of Negative Impact on Lake Baikal

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**Abstract:** The paper presents the results of complex geoecological, hydrochemical and water-ecological studies of the mouth area of tributaries and shores of Lake Baikal at model sites. The mouth area of tributaries is in dynamic interaction with the receiving water body; chemical and biological accumulative and exchange processes directly affect the state of the Lake Baikal's water resources. The study assessed the transformation and determined potential resilience of the main components of landscapes to anthropogenic loads within the mouth area. Revealed are the basic parameters of soil and surface water pollution and factors of anthropogenic influence of residential and recreational zones on the natural complexes of the model territories. The research results showed that the pollutant accumulation on the geochemical barriers of soils and alluvial deposits, purification of surface waters in floodplain meadow and wetlands are quite active and generally support the ecological state of the mouth area. However, the low degree of resilience to anthropogenic loads and the current level of degradation of the landscape components of mouth complexes indicate the need to reduce the adverse impact on these territories and on the lake ecosystem as a whole.

**Keywords:** coastal ecosystem; environmental situation; landscape; surface waters; soil; vegetation; snow



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## 1. Introduction

Lake Baikal is a unique, oldest, largest and deepest freshwater water body on the planet, containing 20% of the world's fresh water. The increasing water scarcity in the world and current ecological issues of Lake Baikal indicate the need for enhancing environmental activities aimed at the protection of the lake and its watershed area and at minimizing the adverse anthropogenic impact on the lake ecosystem. Lake Baikal is a World Natural Heritage Site [1] and is subject to the law of the Russian Federation "On the Protection of Lake Baikal" [2]. However, constant adjustments to legal acts and environmental standards, climatic changes and increasing anthropogenic loads on the lake ecosystem have been leading to environmental deterioration of the water object.

Significant negative tendencies can be traced in the mouth area of tributaries and on the coastal strip adjacent to settlements; within the swash zone and in the littoral of the reservoir; in recreational areas and unregulated tourism destination on the shore. Many scientists emphasize the deterioration of the ecological state of the lake caused by the increased tourist impact and pollution of the lake due to wastewater discharges. The influx of pollutants with the waters of the tributaries, intensification of eutrophication of shallow coastal areas of the lake in the context of an excess of nutrients, mass reproduction of algae, etc. are noted. These processes are clearly manifested in the areas of southern and northern Baikal near settlements and tourist sites [3–5]. The terrestrial coastal ecosystems experiencing increasing anthropogenic pressures are also degrading [6–8].

The river mouth areas are specific natural complexes located within the zone of constant dynamic interaction, channel-forming, abrasion, accumulative and exchange chemical and biological processes of the watercourse and receiving reservoir. Periodic water logging and flooding of the territory, the transfers of substances from the catchment area and anthropogenic load on the coastal zones determine the transformation of the landscape structure and the chemical composition of water and soil.

To preserve the ecosystem of a unique water body, it is necessary to study the processes in these zones, assess the degree of environmental change, determine the level of economic development of coastal territories and find ways to reduce the negative impact on the lake.

The research focus is on the assess of the current state and determination of the transformation factors and degree of the components of natural complexes in the mouth areas of the tributaries of Lake Baikal (as exemplified by the rivers: Goloustnaya, Sarma, Kika and Barguzin). The work provided insight into the degree of anthropogenic disturbance and stability of the components of natural complexes of the mouth areas of individual tributaries of Lake Baikal (Figure 1).

## 2. Materials and Methods

### 2.1. Study Area

The rivers chosen for research flow into Lake Baikal from opposite shores—from the northwest and southeast. The rivers' mouth areas belong to several administrative entities with different, but relatively low levels of socio-economic development. The main social trends observed in the settlements located on these territories are as follows: rising unemployment, decline in the population and outflow of the population outside the region [9]. Subsidiary, household and small farms are widespread in the settlements of the mouth areas; the population density is low, with the exception of the settlement of Ust'-Barguzin.

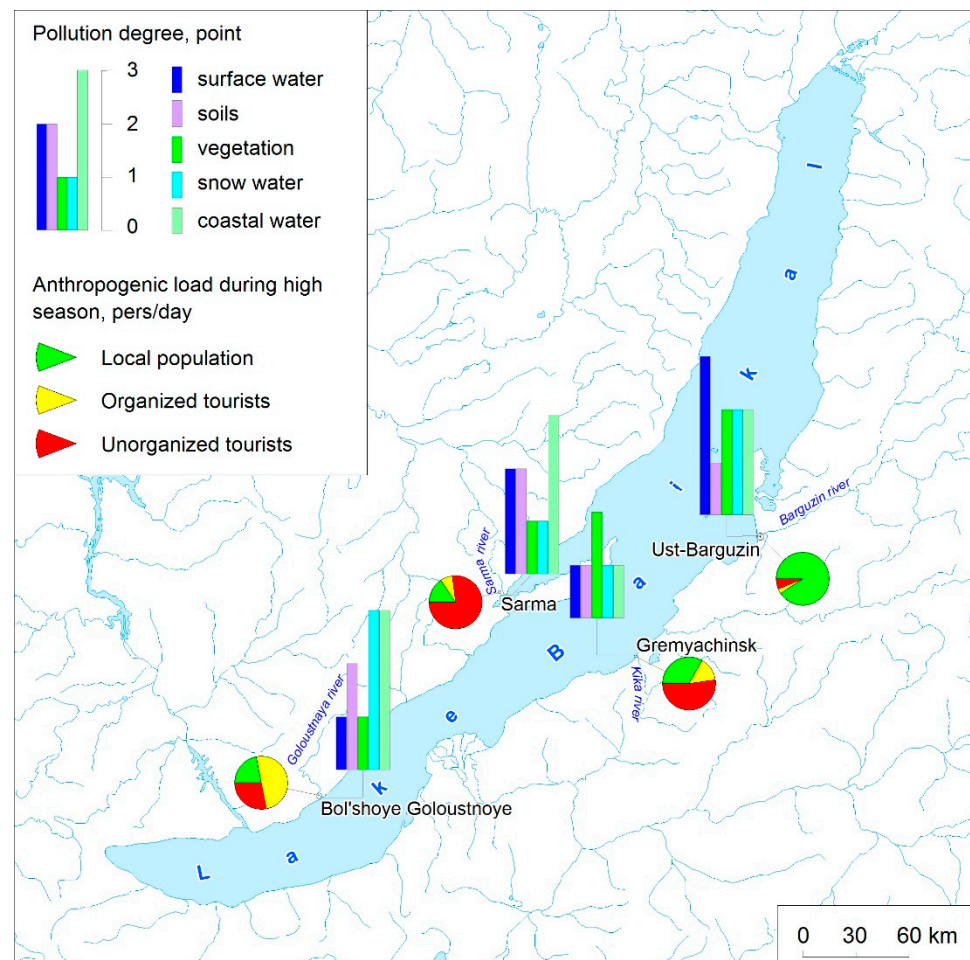
The major trend in the socio-economic development of the territories is the active transformation of the agricultural structure to a predominantly tourist and recreational structure. There is a significant increase in the tourist flow, which, given the lack of adequate social and communal infrastructure in municipalities, causes serious environmental problems, having a negative impact on the natural components of the mouth and coastal zones.

The Goloustnaya, Sarma and Kika rivers are small streams. However, the Barguzin river is a relatively large river with a catchment area of about 20,000 km<sup>2</sup> and an average water discharge of 123 m<sup>3</sup>/s (Table 1). The rivers are characterized by rare spring-summer floods and high floods, which are formed on the slopes of the mountainous surroundings of Lake Baikal and account for more than 50% of the annual runoff. Floods are usually observed in July–August, but in high-water years, they can overlap with high-water periods in spring or follow one after the other [10,11] (State Water Register, Online Database of the State monitoring of bodies of water). River basins cover mountainous and foothill taiga territories, poorly transformed in the upper and middle parts of the catchment. The main landscape changes are observed in the lower parts of the catchments in single small settlements. Only on the Barguzin river there are several villages and the forestry work is underway. The main anthropogenic impacts on the natural components of the catchment area are registered at mouth areas.

**Table 1.** Hydrological characteristics of the rivers.

River, Locality	Catchment Area, km <sup>2</sup>	Average Long-Term Water Flow, m <sup>3</sup> /c		
		Annual	Maximum	Minimum
Goloustnaya–vil. Bol. Goloustnoe	2260	9.57	74.7	2.08
Sarma–vil. Sarma	787	4.81	74.1	0.12
Kika -vil. Khaim	2010	24.8	168	4.17
Barguzin–vil. Barguzin	19,800	123.0	1110	11.5

Within the mouth area, the rivers of the northwestern coast, Goloustnaya and Sarma, have a delta extended into the lake up to 2 km with meandering channels (Figure 1). Within the delta of the Goloustnaya river and on the adjacent coastal area, the residential zone (including the recreational area) occupies about 10% of the entire mouth area [12]. Within the Sarma river delta, the housing and outbuildings occupy up to 5% of the delta area. The mouth channels, transformed after bank protection measures and dredging, now have an artificial channel connecting the river with the lake. Long-term agricultural and current recreational impacts have caused natural suppression, degradation of meadow and bog complexes in mouth areas.



**Figure 1.** Ecological state of the mouth areas of model tributaries of Lake Baikal.

On the southeastern coast, we studied the Kika and Barguzin rivers. The Kika river flows through a wetland in the lower reaches, strongly meandering, then cuts through a multi-meter sandy beach, forming a small bay when it flows into Lake Baikal. Recreational activities develop on the coast of the lake adjacent to the confluence of the river. The Barguzin river forms a large bay with sandy shallows and spits when flowing into the lake. The mouth area of the Barguzin has been experiencing significant anthropogenic impacts. Vast meadow spaces of the valley and terraces of the Barguzin river are occupied by residential buildings and household facilities, and, consequently, the land cover is changed. The coastal area of the Barguzin Bay has the status of a specially protected natural area but is used for recreation.

## 2.2. Field Studies

We conducted comprehensive research of the mouth areas based on geoecological, geochemical and water-ecological analyzes of the territories. Namely, we carried out experimental work, including sampling of water, snow, soil and vegetation in 2015–2019 within the mouth and coastal areas of the lake. The sampling was carried out at key sites, taking into account the sources and direction of intake of pollutants. In total, we took 188 samples of soils and plants in the summer period (July to August); 191 snow samples in the spring and winter period (February to March); 189 samples of surface water in the winter-spring, summer and autumn periods in the phase of minimum runoff (February to March, July to August and September to October). The snow samples were taken with a VS-43 snow meter throughout the entire thickness of the snow cover with determination of its height and density (weight) during the period of maximum snow accumulation (130–140 days). The water samples from rivers were taken with glass bottles at a distance of 5–10 m from the coast from a depth of 1 m. The coastal waters of Lake Baikal were taken at a distance of 10 m from the coast from a depth of 50 cm. The soil and vegetation samples were taken on the main elements (forms) of the relief at various distances from pollution sources. The soil samples were taken from all horizons to the depth of the soil profile; several soil samples were taken if the horizons were more than 20 cm thick. Figure shows an example of the sampling point location within the Barguzin, Goloustnaya, Sarma and Kika river mouths (Supplementary Materials, Figures S1–S4).

## 2.3. Laboratory Analyzes

We performed chemical analyzes at the Laboratory of Landscape Geochemistry and Soil Geography and at the Chemical Analytical Center of the Sochava Institute of Geography SB RAS according to standard methods (GOST) using modern equipment. Several elements were determined in a field chemical laboratory directly on the day of sampling according to standard methods, taking into account the requirements of GOST [13–17].

The pH value, the content of fluorides, chlorides, hydrocarbonates, phosphates, ammonium, nitrites, and suspended solids in water were analyzed during field research using a field complex chemical laboratory with additional equipment (pH-tester, photoelectric colorimeter, etc.) on the day of sampling according to the GOST requirements. The water acidity (pH) was measured by the potentiometric method, the content of hydrocarbonates in water-by the titrometric method, the mass concentration of nitrites-by the photometric detection employing the Griess reagent, and the chloride content-by the argentometric method. Concentration of nitrates was detected by photometric method using salicylic acid, ammonium ion content-by photometric detection employing Nessler's reagent and phosphate concentration-by photometric detection through deoxidization with ascorbic acid. The fluorine content was measured photometrically using lanthanum alizarincomplexone. The content of metals was determined by the quantitative atomic emission spectral method using the *Ortima 2000DV* device. The concentration of petroleum products was determined using the fluid analyzer *Fluorate*. The water samples for determining the concentration of heavy metals were preserved with hydrochloric acid and stored in glassware for no more than 5 days. The samples for the determination of the content of petroleum products were preserved with chloroform and stored in dark glass containers for no more than 3 days in a cool place. The snow samples were stored frozen for up to 10 days. The soil samples for the determination of oil products were taken in foil and stored for no more than 10 days. The soil samples for the determination of heavy metals were dried to room temperature and stored in cotton bags for up to 20 days.

## 2.4. Ecological Status Assessment

To determine the degree of soil stability, we used the average data on the properties of various soil types that are sensitive to possible anthropogenic impacts. The soil sensitivity to technogenic and recreational impacts (mechanical disturbance and chemical pollution) was assessed in three categories (high, medium, low) based on soil (humus con-

tent, acidity, structure, density and grain size distribution) and geomorphological (surface slope) indicators.

The Supplementary Materials contains the maximum, minimum and average values of the content of chemical elements and substances in various components of landscapes, calculated based on samples taken for many years of research (Supplementary Materials, Tables S1–S3). The long-term average values were obtained by averaging the data over the observation periods (the period of field research) and over the years. The background content of chemical elements is given as an average for the “conventionally clean” (background) territory.

The pollution degree of natural components was assessed focusing on the maximum and approximate permissible concentrations of pollutants (MPC and APC) in soils, vegetation and surface waters [18–24]. To compare the obtained indicators in different mouth areas, we introduced generalized characteristics of the pollution level and the general ecological state. Points, according to which we classified the groups of low, medium and high pollution degree, display contamination of soil, vegetation, snow and water and result in the frequency with which MPCs is exceeded by 1–2 times (1 point); 2–5 times (2 points) and more than 5 times (3 points) (Table 2).

**Table 2.** Contamination of landscape components of mouth areas of the tributaries and coastal water area of Lake Baikal.

Mouth Area	River Water		Soils		Vegetation		Snow Water		Lake Water		Mouth Area, Taken as a Whole	
	the MPC Exceedance Frequency, Times	Points	the MPC Exceedance Frequency, Times	Points	the MPC Exceedance Frequency, Times	Points	the MPC Exceedance Frequency, Times	Points	the MPC Exceedance Frequency, Times	Points	Contamination	Points
Goloustanya	<1	1	1.2–3.8	2	<1	1	>5	3	1–7	3	High	10
Sarma	3–5	2	1.2–4	2	<1	1	<1	1	<1	1	Medium	7
Barguzin	1.6–77	3	<1	1	1–3.5	2	3–5	2	1–10	3	High	1
Kika	1–2	1	<1	1	1–2	2	<1	1	<1	1	Medium	6

The transformation of natural landscapes of mouth areas and their ecological state was analyzed by generalizing individual expert’s assessments of anthropogenic loads taking into account the sustainability degree of natural components to different impacts (Table 3).

**Table 3.** Stability of surface water and landscape components of mouth areas to anthropogenic impact.

Mouth Area	Surface Water (Self-Purification)	Floodplain–Channel Complex	Soils	Vegetation	Natural Mouth Area, Taken as a Whole
Goloustanya	Low	Low	Medium	Medium	Medium
Sarma	Low	Low	Low	Medium	Low
Barguzin	Medium	Medium	Medium	Medium	Medium
Kika	Low	Medium	Low	Low	Low

The ecological state of the territory was analyzed according to the principles of “Environmentally oriented land use planning” developed by the staff of the Sochava Institute of Geography SB RAS for a Russian territory on the basis of the European methods “Landscape planning” [25,26]. Identification of the sustainability degree of surface waters, soils and vegetation to anthropogenic impact and the levels of the ecological state was carried out using the methodology for determining the significance, sensitivity and stability of the main components of landscapes in landscape planning and other assessment methods [27,28].

For areas with natural land cover, the main assessment criterion is the ability to maintain the natural biological productivity of plant communities. For each type of landscape, we took into account terrestrial vegetation mass, established the relationship between vegetation and soils, including such soil parameters as the thickness of the humus horizon, grain size distribution, stony content, swampiness and permafrost. The anti-erosion resistance of soils is determined, first, by the state of vegetation, since the developed vegetation cover is a factor in preventing erosion. When determining the sustainability of

vegetation to chemical pollution, we took into account their ability to accumulate chemical elements from the soil (coefficient of biological absorption) [29,30].

Quantitative and qualitative indicators of the surface water state were determined by climatic factors and the conditions for the flow of natural waters from the catchment into the water body. Furthermore, there is a direct dependence of the state of the watercourse on the landscape structure of the catchment and its disturbance. For water bodies, we analyzed the states of the catchment area, the floodplain–valley complex and the channel system, where as the main factors were taken the humidity criteria, moisture capacity and permeability of the soil-ground layer, erosion processes, etc. The criteria for assessing the watercourse stability were its hydrometric and hydrophysical criteria, intensity and directivity of the channel process and deformations, sediment transport, content of pollutants, etc.

The meadow-bog complexes in the valleys of the mouth areas have high accumulating capacity and serve as filters on the way of contaminants entering both the watercourse and the receiving water body. Significant purification of surface waters (hillwash) is caused by accumulation processes and delayed water loss in these areas. It should be borne in mind that the accumulation of pollutants occurs in floodplain–valley meadow-bog landscapes, and anthropogenic changes in such areas lead to disruptions of the accumulating and filtration functions of these landscapes and, consequently, the possible entry of pollutants into the water body. However, the coastal areas directly adjacent to watercourses and Lake Baikal have the status of water protection zones with regulatory restrictions on economic activities and should not undergo significant transformations of land cover [31].

A set of such parameters is used to assess the current state (in comparison with the background characteristics) and possible changes due to violations, which evidence for findings relating to the level of the ecological state of the natural territory.

The signs of the ecological state category are negative changes in the natural environment: degradation of the land cover, pollution of the aquatic environment, decrease in biological diversity, etc. Ecological stress can be characterized as negative changes in the ecosystem, the restoration of which to its original state is possible with the complete removal of anthropogenic loads. An ecological crisis is a stable irremediably adverse change in the components of an ecosystem [28]. However, after complete release of the load, reclamation and remediation, it is possible to create an ecologically favorable state, but the restoration of the original state of nature is impossible.

Three ecological state categories are identified as favorable, stressful and crisis.

### 3. Results and Discussion

Comprehensive research of the mouth zones and adjacent areas of the Baikal coasts is aimed at studying the transformations of natural components-soils, vegetation and surface waters, as well as the determination of the potential stability of landscape components against natural and anthropogenic changes.

The performed theoretical, analytical and field works made it possible to analyze the current state and stability of individual components of landscapes and to draw conclusions about the disturbance degree.

#### 3.1. Soils

Different types of soils have varying degrees of resilience to withstand chemical and mechanical anthropogenic impact. The study identified two large subdivisions of soils with varying degrees of stability to the anthropogenic impact on the study areas locating on the shore of Lake Baikal [29].

Very cold, freezing for a long time, moderately moist, light soils, on steep rocky slopes with a poorly developed soil profile and sparse vegetation cover, have low stability. The unregulated anthropogenic impact on areas with these soils can provoke the destruction of the sod horizon and the activation of erosion processes.

Low stability is also inherent in soils of medium thickness, which are subject to periodic excessive moisture (flooding), and characterized by close permafrost and possible

salinization. The active period of soil formation in such areas is reduced and leads to inhibition of vegetation development.

Medium-thick, loamy, moderately and periodically insufficiently moist cold and long-term freezing soils on leveled elevated surfaces have a medium stability.

The unregulated anthropogenic impact reduces the stability of soils and causes the activation of linear erosion, which locally interrupts the biogeochemical cycle and enhances the geological one.

Soils are a natural biogeochemical barrier to the migration of pollutants into the water body (Lake Baikal). The sorption intensity of toxic substances depends on the soil type, on the content of colloids capable of adsorbing ions, as well as exchanging absorbed ions for ions of aqueous solutions. Soils with an alkaline reaction, heavy granulometric composition and a significant organogenic and humus-accumulative horizon have the highest sorption capacity in the research territory. Such high ecological properties are characteristic of the floodplain soils of river mouths, due to the large amount of silt. At the same time, under an active anthropogenic pressure, the sorption effect can decrease and chemical elements are washed out of the soil. The soil contamination was assessed in comparison with the MPC and is shown in Table 2 [18,19,24].

The soils of the Goloustnaya river mouth are mainly represented by alluvial dark-humus, chernozemic and alluvial humus soils. There are dark and gray-humus metamorphosed leached soils, as well as alluvial peat-gley soils. The soils mainly have a light loamy granulometric composition, average thickness of the humus horizon (6–30 cm), high humus content (4–>10%) and neutral and slightly alkaline environment, with the exception of alluvial peat-gley soils. The manganese (Mn), nickel (Ni) and chromium (Cr) contents in soils exceed the MPC and APC by 1.2–3.8 times (Supplementary Materials, Table S3), which is associated with their natural origin. The high Mn and Ni content in the upper horizons is caused by their biogenic accumulation. The source of the high Cr content is carbonate parent rocks. Pollutants are sorbed on organogenic, humus-accumulative and alkaline barriers. Some of the toxic substances are captured by silty particles of the floodplain soils. However, several types of the presented soils have a light loamy granulometric composition, which indicates their high sorption properties and, in general, the medium stability level of soils of the Goloustnaya river mouth to the anthropogenic impacts.

The mouth of the Sarma river is represented by chernozems, chestnut-like, alluvial dark-humus and alluvial peat-gley soils. Chestnut, chernozemic, stratified alluvial, and gray-humus soils are also found here [30–33]. The soils are generally shallow, stony, have a light particle size and a high humus content. The ecological state of the Sarma river mouth can be characterized as a moderately polluted. The Mn, Cr, Cu, Ni and Pb concentrations in steppe soils exceed the MPC and APC by 1.2–4 times (Supplementary Materials, Table S3, Table 2). However, several researchers note that many macro- and microelements in soils that exceed the MPC are of natural origin and come from parent rocks [34]. In the territories adjacent to the lakeshore and the Sarma river mouth, there are deposits of copper, iron and manganese ores [35,36], which are the input sources of chemical elements into soils.

The content of heavy metals in the soils of meadow and meadow-bog landscapes does not exceed the sanitary and hygienic standards. The soils under recreational objects have a high organic matter content. They are slightly alkaline and alkaline, which contributes to the accumulation of heavy metals, characterizing the soils as a deposit environment, a certain “geochemical barrier” [37,38] for the input of pollutants into Lake Baikal. However, the light grain size distribution (often sandy-loam and sandy with a low content of silty particles) of these soils greatly reduces their protective properties.

The soils of the Barguzin river mouth are represented largely by alluvial humus-gley and alluvial peat-gley species. There is also alluvial dark humus, alluvial humus and stratified alluvial soils here [30,39,40]. These soils are predominantly slightly acidic and neutral, characterized by a good ecological state, powerful organogenic and humus horizons. The carbon content in soils is high, and concentration of heavy metals and other toxic elements does not exceed the MPC and APC (Table 2). Powerful peaty and humus

horizons are capable of absorbing a significant number of pollutants. The soils have a medium degree of stability against anthropogenic impact.

The soils at the mouth of the Kika river are underdeveloped, thin, have light granulometric composition with a low humus content and a neutral reaction of the environment. The background composition of soils is represented by stratified alluvial, alluvial humus, psammozems; in some places gray-humus and dark humus soils are found. The content of macro- and microelements in soils does not exceed the MPC and APC (see Table 2). Soils with low stability to anthropogenic impact, often sandy-loam and sandy with a predominance of sandy fraction, through which toxic substances easily migrate into water bodies (Table 3).

### 3.2. Vegetation

We identified three groups of plant communities by analyzing the vegetation of the model areas of the coast of Lake Baikal according to the soil stability level to anthropogenic impacts.

The sparse vegetation cover of steep slopes, formed on stony thin soils, had a low stability level. The anthropogenic transformation of such areas destroyed vegetation, as well as erosion and solifluction processes. The vegetation of permafrost landscapes also had low stability. Permafrost, being disturbed, activated the processes of waterlogging, which led to a change of vegetation.

Steppe and forest-steppe complexes can be characterized by medium stability level. These plant communities have a high toxicity threshold and stability to anthropogenic pollution with low stability to structural damage [41,42].

Medium and above medium stability levels are typical for light coniferous and dark coniferous forests of terraces and valley slopes. The relatively thick soil cover and smooth slopes prevent the rapid development of vegetation degradation processes. Noteworthy that woody species of vegetation are sensitive to pollution and have a low toxicity threshold. Even a small accumulation of toxic elements leads to suppression of woody plants [41,42]. Parvifoliate species are more resistant to anthropogenic influences than coniferous [43]. High stability is characteristic of meadow and meadow-bog complexes that play a significant ecological role in river mouth systems. Steppe vegetation is capable of accumulating more toxic substances without suppression of its basic life functions than forest vegetation [41,44].

The lower areas of the Goloustnaya river mouth are represented by forb-grass meadows. The slopes and coastal areas of the lake adjacent to the delta are occupied by steppified pine and larch forests, which are quite sensitive to changes in nature. Anthropogenic changes of these landscapes lead to the intensification of the overland runoff, development of erosion processes, input of erosion products and sheet flood into the mouths of streams and further into the lake. Meadow vegetation, due to its root system, is highly resistant to mechanical stress. In general, the vegetation cover of the Goloustnaya river mouth has medium and above medium stability to anthropogenic influences and an intermediate disturbance.

Plant communities of the Sarma mouth area range from dry steppes at the top of the delta to swampy meadows on the shores of Lake Baikal. Most of the territory is covered with lithophilic steppes in conjunction with fescue and petrophytic herb-bunchgrass plant aggregation. Meadow vegetation is quite resistant to anthropogenic influences, in contrast to the sparse stony steppes on the slopes. In areas with a high recreational load, soil over consolidation and erosion we observed a lower productivity of vegetation [12,45]. In fact, the vegetation of the Sarma river mouth has a medium stability degree to anthropogenic impacts.

The valley slopes at the mouth of the Barguzin river are occupied by pine grass forests with shrub undergrowth mixed with parvifoliate and coniferous trees and are quite sensitive to anthropogenic impacts. The lower part of the Barguzin river mouth area is represented by sedge-reed meadows and herbaceous wetlands, there is permafrost in some areas. The floodplain meadow-bog complexes are generally characterized by high stability, but in the areas of permafrost, the stability of plant communities is low. The vegetation of the Barguzin river mouth area has a medium stability degree to anthropogenic influences.



The vegetation cover at the Kika river mouth is sparse and fragmented, mainly represented by steppe meadows, sagebrush-grass steppe and meadow-bog complexes. There is no vegetation on the lakeshore. The slope surface and elevated areas are covered with pine and larch-pine subshrub-grass forests. A very light texture of soils and a sparse vegetation cover determine the low resistance of the river mouth landscapes to anthropogenic impacts (see Table 3). However, under low anthropogenic load, we observed degradation of the vegetation cover only fragmentarily in some areas.

The coefficient of biological absorption [32,37] of Mn, Sr, Mg by vegetation of steppe and meadow landscapes from the soils of the Goloustnaya and Sarma river mouths varies in the range from 1.3 to 2.0 times. However, the content of macro- and microelements in plants does not exceed the sanitary and hygienic standards for raw plants. At the mouths of the Kika and Barguzin rivers, an increased copper (Cu) content in plants was 2 and 3.5 times higher than the MPC, respectively, with a low content of other macro- and microelements in plants. In the vegetation of meadow and meadow-bog associations, we recorded a significant amount of trace elements. The vegetation contamination was assessed in comparison with the MPC and is shown in Table 2 [24,32,37].

### 3.3. Snow and Surface Water

The contamination of substrate, resulted from the atmospheric transport of chemicals, was determined by the pollutant content in snow. The snow cover has a high sorption capacity and is the most informative-bearing object for identifying technogenic pollution of the underlying surface.

The study of the chemical state of snow water from the ice of the water area of Lake Baikal at the confluence of the tributaries showed that the the Sarma and Kika rivers' mouths were free of contamination, and the content of macro- and microelements did not exceed the MPC. Recorded was excess of background values of hydrocarbonates, sulfates, sodium, lead, aluminum, manganese, iron and titanium in snow waters at the mouths of the Goloustnaya and Barguzin. Phosphate concentrations are the highest in these areas. At the mouth of the Barguzin, the phosphate content exceeds the MPC by 3–5 times, and at the Goloustnaya river mouth up to 8 times [46]. The increased content of chemical elements in snow is due to the atmospheric transfer of emissions from urbanized areas and wind transfer of terrigenous dust and soil particles from snowless steppe areas.

We analyzed the surface water stability to anthropogenic impacts based on an assessment of the self-purification properties of a watercourse, which depend on its hydrological, biological and chemical characteristics. The self-purification properties are mainly determined by the flow rate, water volume and temperature characteristics. Moreover, the larger and faster the river, the higher the level of self-purification [47]. The large Barguzin river has satisfactory self-purification properties among all rivers under study, taking into account the combination of hydrological parameters. The small rivers Sarma, Goloustnaya and Kika are characterized by low self-cleaning abilities, since small volumes of runoff and low water temperature of streams do not provide conditions for dilution, intensive mixing, active redox processes, etc. (see Table 3).

The contamination of snow and surface waters was assessed in comparison with the MPC for fishery reservoirs and is shown in Table 2 [15,20].

The analysis showed that the content of trace elements in the delta waters of the Goloustnaya and Kika rivers does not exceed the sanitary and hygienic standards. High concentration of phosphates ( $\text{PO}_4$ ) was found in the water of the Sarma river ( $0.06 \text{ mg/dm}^3$ ). The maximum pollution was observed in the water of the Barguzin river, with the concentrations of oil products ( $0.08 \text{ mg/dm}^3$ ), lead (Pb) ( $0.020 \text{ mg/dm}^3$ ) and phosphates ( $\text{PO}_4$ ) ( $0.08 \text{ mg/dm}^3$ ) exceeding the MPC. In addition, in the water of the Barguzin river, an excess of the background level was recorded for iron (Fe) (up to  $0.24 \text{ mg/dm}^3$ ) and zinc (Zn) (more than  $0.01 \text{ mg/dm}^3$ ). The content of copper (Cu) exceeding the background by 1.5–2 times (up to  $0.04 \text{ mg/dm}^3$ ) is observed in the surface waters of the mouths of the Kika and Barguzin rivers.

Hydrochemical studies of the coastal waters of Lake Baikal, adjacent to the mouth areas of the tributaries under study, showed concentrations of lead (Pb), nickel (Ni), phosphates (PO<sub>4</sub>) and oil products exceeding the sanitary and hygienic standards. Significant exceeding background concentrations of copper (Cu) and zinc (Zn) (more than 0.01 mg/dm<sup>3</sup>) were observed in the waters of the lake in the mouth zones of the Goloustnaya and Barguzin rivers. In the mouth of the Goloustnaya river, high content of oil products (0.06–0.34 mg/dm<sup>3</sup>), exceeding the MPC up to 7 times was recorded. In the mouth area of the Sarma river, the concentration of phosphates (PO<sub>4</sub>) (0.01 mg/dm<sup>3</sup>) is 10 times higher than the MPC. High concentrations of the main pollutants are caused by the influx of emissions and discharges from residential, economic and recreational areas of the shore, as well as river runoff from the catchments of the rivers. At the same time, a significant content of lead (Pb) in the coastal waters of Lake Baikal (near the mouth of the Barguzin river 0.020 mg/dm<sup>3</sup>) is mainly associated with the increased presence of this element in soils and parent rocks of the adjacent coastal area [34].

### 3.4. Environmental State

The assessment of the transformation degree of natural landscapes of mouth areas and their environmental state was made by generalizing individual experts' assessments of anthropogenic loads, taking into account the resilience of natural components under stress (see Tables 2 and 3). We distinguished three ecological state categories—favorable, stressful and crisis (Table 4).

**Table 4.** Ecological state of the mouth areas of the tributaries of Lake Baikal [25–28].

Mouth Area	Landscapes		Local Population and Tourists in High Season, Per/Day *	Integral Indicator of Ecological State
	Stability	Contamination		
Goloustanya–vil. Bol. Goloustnoe	Medium	High	2000–3000	Critical
Sarma–vil. Sarma	Low	Medium	100–1000	Environmental stress
Barguzin–vil. Ust'-Barguzin	Medium	High	7000–8000	Critical
Kika–vil. Gremyachinsk	Low	Medium	2000–3000	Environmental stress

\* Population and recreational data for 2017–2019 [6,7,12].

The greatest pollution is observed at the mouths of the Goloustnaya and Barguzin rivers. For the Goloustnaya river soil and snow pollution results from atmospheric transport of emissions from the Irkutsk industrial center. The resilience of the landscapes here is not high, anthropogenic load is high, spatial differentiation of economic and recreational objects on the territory is significant, which determines a high level of anthropogenic impact. Intensive natural hydrological and geomorphological processes contribute to erosion and abrasion processes leading to horizontal and vertical deformations of the floodplain–channel mouth system. Eventually, the ecological state of the mouth area is assessed as a crisis.

The most transformed landscapes are found at the mouth of the Barguzin river. With due regard for relatively good potential for self-purification, the water in the river is highly polluted, mainly because of the influx of pollutants from the upstream catchment areas. Low soil stability, medium indicators of pollution and stability of vegetation under high economic and recreational loads caused an unfavorable critical ecological state of the territory.

In the mouth zone of the Sarma river, the main pollutants are formed as a result of recreational activities and enter the soils and river and lake waters. The rather low stability of the landscapes of the territory and the self-purification of river waters are combined with the medium level of anthropogenic impacts and floodplain–channel deformations. In general, the landscapes of the mouth area of the Sarma river can be characterized as moderately disturbed, and the general ecological state as stressful with a high degradation degree of individual areas of the soil and vegetation cover.

The landscapes at the mouth of the Kika river are the least stable to anthropogenic loads, the soils and vegetation of which consist of species and types which are sensitive

to impacts. The area experiences significant recreational loads, but has a relatively low level of soil and water contamination. With due regard for the low stability of landscapes and given the fact that landscape changes are inevitable under increasing anthropogenic pressure; the overall ecological state of the territory is assessed as stressful (see Table 4).

#### 4. Conclusions

A comprehensive analysis of the research materials concluded pollution and stability of the landscapes in the mouth areas of the tributaries. We revealed that the pollution of soils, vegetation and the coastal water area of the lake within the mouth zones of the model tributaries is primarily due to the residential and recreational use of the territory.

The research of coastal lake waters revealed that the accumulation processes of pollutants on geochemical barriers, in alluvial sediments and floodplain meadow-bog landscapes are quite active. The research results show a significant protective role of river mouth landscapes for the water area of Lake Baikal. The mouth area of the rivers under study and other tributaries of the lake, however, are subject to strong anthropogenic impacts, characterized by an increased content of pollutants in the coastal waters of Lake Baikal, landscapes and river waters and require restrictions on recreational activities, strengthening environmental protection measures and monitoring their implementation.

Mouth territories of the Goloustnaya and Barguzin rivers need functional zoning with the allocation of zones of different environmental regimes and the arrangement of the territory, given the sustainability of landscape components. The impact intensity on landscapes should not exceed the resilience of natural complexes. Remedial clean-up activity, pollution prevention and subsequent strict control over compliance with restrictions, especially in residential and recreational areas of the mouth areas and coasts of water bodies.

The mouth areas of the Sarma and Kika rivers most need measures to reduce the degradation of the land cover, to ban all types of impacts leading to disturbance of the soil cover and intensification of erosion processes in these territories. Here it is necessary to regulate the number of tourists and build pedestrian paths; prohibit the passage of vehicles, plow the land and apply fertilizers; and to remedy the damage.

For the study area, however, it is necessary to comply with the norms and restrictions in the water protection zones of water bodies.

In general, an obligatory stage in reducing the uncontrolled anthropogenic impact on the mouth areas of the tributaries and the shores of Lake Baikal is a development plan, taking into account environmental restrictions and the creation of an environmental infrastructure. Such measures will take into account alternative social and environmental aspects of use and strengthen the protection of the natural components of the territories. It should be noted that this process has been developing and certain results have been already achieved [7,48].

**Supplementary Materials:** The following are available online at <https://www.mdpi.com/article/10.3390/w13091295/s1>, Figure S1: The Barguzin river mouth, sampling point location (Sentinel-2, 03.07.2020), Figure S2: The Goloustnaya river mouth, sampling point location (Sentinel-2, 09.06.2020), Figure S3: The Sarma river mouth, sampling point location (Sentinel-2, 04.09.2020), Figure S4: The Kika river mouth, sampling point location (Sentinel-2, 04.09.2020), Table S1: The content of oil products and main ions in the water of the Goloustnaya, Sarma, Kika and Barguzin rivers, in the coastal waters of Lake Baikal and in the snow waters of deltas according to the field research data in 2015 to 2019, Table S2: The gross content of heavy and alkali-earth metals in the water of the Goloustnaya, Sarma, Kika and Barguzin rivers, the coastal waters of Lake Baikal, snow waters of deltas according to the field research data in 2015 to 2019, Table S3: The gross content of oil products, heavy and alkali-earth metals in the upper soil horizons (0–20 cm) and sedimentary ash in the mouths of the Goloustnaya, Sarma, Kika and Barguzin rivers according to the field research data in 2015 to 2019.

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## References

1. Lake Baikal—Documents—UNESCO World Heritage Centre. Available online: <http://whc.unesco.org/en/list/754/documents/> (accessed on 1 February 2021).
2. The Federal Law of Russia No. 94-FZ Dated 01.05.1999 “On the protection of Lake Baikal” (with Amendments as of 28.06.2014). Available online: <http://pravo.gov.ru/proxy/ips/?docbody=&nd=102059482> (accessed on 1 February 2021).
3. Timoshkin, O.A.; Samsonov, D.P.; Yamamuro, M.; Moore, M.V.; Belykh, O.I.; Malnik, V.V.; Sakirko, M.V.; Shirokaya, A.A.; Bondarenko, N.A.; Domyshva, V.M.; et al. Rapid ecological change in the coastal zone of Lake Baikal (East Siberia): Is the site of the world’s greatest freshwater biodiversity in danger. *J. Great Lakes Res.* **2016**, *42*, 487–497. [CrossRef]
4. Khanaev, I.V.; Kravtsova, L.S.; Maikova, O.O.; Bukshuk, N.A.; Sakirko, M.V.; Kulakova, N.V.; Tatyana, V.; Butina, T.V.; Nebesnykh, I.A.; Belikov, S.I. Current state of the sponge fauna (Porifera: Lubomirskiidae) of Lake Baikal: Sponge disease and the problem of conservation of diversity. *J. Great Lakes Res.* **2018**, *44*, 77–85. [CrossRef]
5. Timoshkin, O.A. Coastal zone of the world’s great lakes as a target field for interdisciplinary research and ecosystem monitoring: Lake Baikal (East Siberia). *Limnol. Freshw. Biol.* **2018**, *1*, 81–97. [CrossRef]
6. Vorobyeva, I.B.; Vlasova, N.V.; Belozertseva, I.A.; Gagarinova, O.V. Tourism on the south-west coast of lake Baikal as a factor of aggravating environmental problems. *Serv. Tour. Curr. Chall.* **2019**, *13*, 70–78. [CrossRef]
7. Evstropyeva, O.V.; Bibaeva, A.Y.; Sanzheev, E.D. Modeling tourist flows at the regional and local levels. Experience of implementation in the Central ecological zone of the Baikal natural territory. *Serv. Tour. Curr. Chall.* **2019**, *13*, 85–97. [CrossRef]
8. Znamenskaya, T.I.; Vanteeva, Y.V.; Solodyankina, S.V. Digression of vegetation and soils of coastal landscapes of Lake Baikal through the examples of attractive tourism areas. *Serv. Tour. Curr. Chall.* **2018**, *12*, 75–86. [CrossRef]
9. Vorobiev, N.V.; Vorobiev, A.N. Local Population and Recreational Development of the Irkutsk Baikal Region. *Serv. Tour. Curr. Chall.* **2019**, *11*, 41–51. [CrossRef]
10. State Water Register. *Long-Term Data on the Regime and Resources of Land Surface Waters*; Gidrometeoizdat: Leningrad, Russia, 1986; Volume 1, Issue 14, p. 363.
11. Online Database of the State Monitoring of Bodies of Water (Russian acronym AIS GMVO). Available online: <https://gmvo.skniivh.ru/> (accessed on 1 February 2021).
12. Evstropyeva, O.V.; Shekhovtsova, T.N. Typological Approach to the Assessment and Regulation of Recreational Stress on the Social Environment on the Example of the Coast of Lake Baikal. *Bull. Natl. Acad. Tour.* **2020**, *1*, 59–63.
13. Alekin, O.A.; Semenov, A.D.; Skopintseva, B.A. *Guide to the Chemical Analysis of Land Water*; Gidrometeoizdat: Leningrad, Russia, 1973; p. 269.
14. Vorob’eva, L.A. (Ed.) *Theory and Practice of Soil Chemical Analysis*; GEOS: Moscow, Russia, 2006; p. 400.
15. GOST 2874-82. Drinking Water. Hygienic Requirements and Quality Control (1982). Available online: <http://gostvoda.ru/d/677526/d14-gost-2874-82> (accessed on 1 February 2021).
16. Arinushkina, E.V. *Manual on Soil Chemical Analysis*; Moscow University: Moscow, Russia, 1970.
17. Shpeyzer, G.M.; Mineeva, L.A. *Guide to the Chemical Analysis of Waters: Methodical Grant*, Irkutsk State University: Irkutsk, 2006: 55. Available online: [http://window.edu.ru/catalog/pdf2txt/170/37170/14182?p\\_page=1](http://window.edu.ru/catalog/pdf2txt/170/37170/14182?p_page=1) (accessed on 1 February 2021).
18. MIC. The Maximum Indicative Concentrations of Chemicals in the Soil. Hygienic Standards of GN 2.1.7.2042-06, 2006. Federal Center of Hygiene and Epidemiology of Rospotrebnadzor, Moscow. Available online: <https://files.stroyinf.ru/Data2/1/4293850/4293850511.htm> (accessed on 1 February 2021).
19. MPC. The Maximum Permissible Concentrations of Chemicals in the Soil: Hygienic Standards of GN 2.1.7.2041-06, 2006. Federal Center of Hygiene and Epidemiology of Rospotrebnadzor, Moscow. Available online: <https://ohranatruda.ru/upload/iblock/c0a/4293850511.pdf> (accessed on 1 February 2021).

20. Hygienic Standards GN 2.1.5.2280-07. Threshold Level Values (TLV) of Chemical Substances in Water of Water Bodies of Domestic Drinking and Cultural and Domestic Water Use. Available online: <https://files.stroyinf.ru/Data1/51/51955/> (accessed on 28 August 2020).
21. Hygienic Standards GN 2.2.5.1315-03. Threshold Level Values (TLV) of Chemical Substances in Water of Water Bodies of Domestic Drinking and Cultural and Domestic Water Use. Available online: <http://docs.cntd.ru/document/901862249> (accessed on 28 August 2020).
22. Hygienic Standards GN 2.1.7.2041-06. Threshold Level Values (TLV) of Chemicals in Soil. Available online: <http://docs.cntd.ru/document/901966754> (accessed on 28 August 2020).
23. Hygienic Standards GN 2.1.7.2042-06. Approximately Permissible Concentrations (APC) of Chemicals in Soil. Available online: <http://docs.cntd.ru/document/901966752> (accessed on 28 August 2020).
24. SanPiN 42-123-4089-86. Threshold Level Values of Heavy Metals and Arsenic in Food Raw Materials and Food Products, 1986. Available online: <https://www.dokipedia.ru/document/5182275> (accessed on 28 August 2020).
25. Antipov, A.N.; Plyusnin, V.M.; Bazhenova, O.I.; Bardash, A.V. *Environmentally Oriented Land Use Planning in the Baikal Region. Baikal Natural Territory*; Publishing house of the V.B. Sochava Institute of Geography SB RAS: Irkutsk, Russia, 2002; p. 103. Available online: <https://www.elibrary.ru/item.asp?id=21748752> (accessed on 21 January 2021).
26. Antipov, A.N.; Kravchenko, V.V.; Semenov, Y.M. *Landscape Planning: Tools and Application Experience*; Publishing house of the V.B. Sochava Institute of Geography SB RAS: Irkutsk, Russia, 2005; p. 165. Available online: [https://www.studmed.ru/antipov-a-n-kravchenko-v-v-semenov-yu-m-i-dr-landshaftnoe-planirovanie-instrumenty-i-opyt-primeneniya\\_4eaba4da104.html](https://www.studmed.ru/antipov-a-n-kravchenko-v-v-semenov-yu-m-i-dr-landshaftnoe-planirovanie-instrumenty-i-opyt-primeneniya_4eaba4da104.html) (accessed on 21 January 2021).
27. *Technogenic Substance Flow in Landscapes and the State of Ecosystems*; Nauka: Moscow, Russia, 1981; p. 256.
28. Methodology Criteria for Assessing the Ecological Situation of Territories to Identify Zones of an Ecological Emergency and Zones of Ecological Disaster (Adopted by the Ministry of Natural Resources of the Russian Federation on 30 November 1992). Available online: <https://sudact.ru/law/metodika-kriterii-otsenki-ekologicheskoi-obstanovki-territorii-dlia/> (accessed on 18 March 2021).
29. Belozertseva, I.A.; Ubugunov, L.L.; Badmaev, N.B.; Ubugunov, V.L.; Dorzhgotov, D.; Batkhishig, O.; Ubugunova, V.I.; Gyninova, A.B.; Balsanova, L.D.; Gonchikov, B.N. Map "Soils of the Lake Baikal Basin", Sc. 1: 2500000, IG SO RAN: Irkutsk, 2015. Available online: <https://www.elibrary.ru/item.asp?id=24268326> (accessed on 21 January 2021).
30. Kuzmin, V.A. *Central Zone Soils in the Baikal Natural Territory: Ecological and Geochemical Approach*; IG SO RAN: Irkutsk, Russia, 2002; p. 166. Available online: <https://books.google.ru/books/about> (accessed on 18 March 2021).
31. Water Code of the Russian Federation, Dated 03.06.2006 N 74-FZ (as Amended on 28.11.2015) (as Amended and Supplemented, Entered into Force on 01.01.2016). Available online: [http://www.consultant.ru/document/cons\\_doc\\_LAW\\_60683/](http://www.consultant.ru/document/cons_doc_LAW_60683/) (accessed on 1 February 2021).
32. Kuzmin, V.A. Soil Cover. In *Soil-Geographical Zoning, Atlas of the Irkutsk Region*; Publishing house of the V.B. Sochava Institute of Geography SB RAS: Irkutsk, Russia, 2004; pp. 40–41.
33. Vorobyeva, G.A. *Soil as a Chronicle of Natural Events in the Baikal Region: Problems of Evolution and Classification of Soils*; IGU: Irkutsk, Russia, 2010; p. 205.
34. Grebenshikova, V.I.; Lustenberg, E.E.; Kitayev, N.A.; Lomonosov, I.S. *Geochemistry of the Baikal Environment (Baikal Geocological Test Site)*; GEO: Novosibirsk, Russia, 2008; p. 232.
35. Antipov, A.N. (Ed.) *Atlas of the Irkutsk Region*; Roskartografiya: Moscow, Russia, 2004; p. 90. Available online: <https://www.elibrary.ru/item.asp?id=22858229> (accessed on 1 February 2021).
36. *The Ecological Atlas of the Baikal Basin*; IG SB RAS: Irkutsk, Russia, 2015. Available online: [https://elibrary.ru/download/elibrary\\_25207934\\_58673226.pdf](https://elibrary.ru/download/elibrary_25207934_58673226.pdf) (accessed on 1 February 2021).
37. Alekseenko, V.A.; Alekseenko, L.P. *Geochemical Barriers*; Logos: Moscow, Russia, 2003. Available online: [https://www.studmed.ru/alekseenko-va-alekseenko-lp-geohimicheskije-barery\\_3d51ce3bb91.html](https://www.studmed.ru/alekseenko-va-alekseenko-lp-geohimicheskije-barery_3d51ce3bb91.html) (accessed on 1 February 2021).
38. Davydova, N.D. Landscape-Geochemical Barriers and Their Classification. *Geogr. Nat. Resour.* **2005**, *4*, 24–30.
39. Ubugunov, V.L.; Ubugunova, V.I.; Tsyrempilov, E.G. *Soils and Landforms of the Barguzin Hollow (in Russian)*; BNT SO RAN: Ulan-Ude, Russia, 2016; p. 209. Available online: [https://www.researchgate.net/publication/305780625\\_Soils\\_and\\_landforms\\_of\\_the\\_Barguzin\\_Hollow](https://www.researchgate.net/publication/305780625_Soils_and_landforms_of_the_Barguzin_Hollow) (accessed on 1 February 2021).
40. Ubugunov, L.L.; Ubugunova, V.I.; Belozertseva, I.A.; Gyninova, A.B.; Sorokovoi, A.A.; Ubugunov, V.L. *Soil Stability, Ecological Atlas of the Lake Baikal Basin*; Map Sc 1: 5 000 000, V.B.; Sochava Institute of Geography SB RAS: Irkutsk, Russia, 2015; p. 40. Available online: [https://elibrary.ru/download/elibrary\\_25207934\\_33392312.pdf](https://elibrary.ru/download/elibrary_25207934_33392312.pdf) (accessed on 1 February 2021).
41. Nechaeva, E.G.; Belozertseva, I.A.; Naprasnikova, E.V.; Vorobyeva, I.B.; Davydova, N.D.; Dubynina, S.S.; Vlasova, N.V. *Monitoring and Forecasting of the Material-Dynamic State of the Geosystems of the Siberian Regions*; Nauka: Novosibirsk, Russia, 2010; p. 315, ISBN 978-5-02-023315-7. Available online: [http://elibrary.ru/full\\_text.asp?id=21683301](http://elibrary.ru/full_text.asp?id=21683301) (accessed on 1 February 2021).
42. Vlasova, N.V. Environmental problems in the development of the northern territories of the Irkutsk region. *Geogr. Nat. Resour.* **2015**, *4*, 127–134. Available online: <http://www.izdatgeo.ru/pdf/gipr/2015-4/127.pdf> (accessed on 1 February 2021).
43. Nechaeva, E.G.; Davydova, N.D.; Shchetnikov, A.I.; Vorobyeva, I.B.; Naprasnikova, E.V.; Kuzmin, V.A. *Trends of Landscape-Geochemical Processes in the Geosystems of Southern Siberia*; Nauka: Novosibirsk, Russia, 2004; p. 184. Available online: [http://elibrary.ru/full\\_text.asp?id=21783852](http://elibrary.ru/full_text.asp?id=21783852) (accessed on 1 February 2021).

44. Davydova, N.D.; Znamenskaya, T.I. *Technogenic Matter in Steppe Landscapes*; Academic Publishing House GEO: Novosibirsk, Russia, 2018; p. 147. [[CrossRef](#)]
45. Znamenskaya, T.I.; Vanteeva, J.V.; Solodyankina, S.V. Factors of the Development of Water Erosion in the Zone of Recreation Activity in the Ol'khon Region. *Eurasian Soil Sci.* **2018**, *51*, 228–235. [[CrossRef](#)]
46. Belozertseva, I.A.; Vorobyeva, I.B.; Vlasova, N.V.; Gagarinova, O.V.; Yanchuk, M.S.; Lopatina, D.N. The Ecological State of the Coast of Lake Baikal and its Impact on the Pollution of the Lake. *Success Mod. Nat. Sci.* **2018**, *11*, 85–95. [[CrossRef](#)]
47. Gagarinova, O.V. Resistance of Natural Waters within the Lake Baikal Basin to Anthropogenic Impacts. *Geogr. Nat. Resour.* **2015**, *96*, 40–47. [[CrossRef](#)]
48. Zabortseva, T.I. Deficiencies and prospects of the environmental protection infrastructure in tourism and recreational development (the central ecological zone of the Baikal natural territory). *Serv. Tour. Curr. Chall.* **2018**, *12*, 52–63. [[CrossRef](#)]