

Microbiological composition of river waters in the Ob' basin (West Siberia) and its associations with hydrochemical indices

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Abstract. Chemical and microbiological composition of the Mid-Ob' and its feeders' waters has been studied. Swampiness of the area is the cause of significant organic and biogenic substance content in streams, and it is also responsible for a large variety of organotrophic microflora. Microbiological composition of studied streams characterizes them as contaminated. Settlements are the main sources of the investigated area water pollution.

1. Introduction

Microorganisms are of vital importance in ecologo-geochemical formation of biosphere components, including aquatic ecosystems. Therefore, quantitative and group compositions of microorganisms are one of the most important criteria of surface water body condition. It is impossible to objectively estimate recent and future condition and plan effective aquatic protection activities without direct knowledge of river water microbiological composition, and this fact determines the relevance of these investigations. The research of microbiocoenosis in Siberian aquatic ecosystems is carried out by scientists (with the participation of authors) of National Research Tomsk Polytechnic University during 1994–2014. The results of one of its stages, which dealt with the Ob' and its inflows water microbiological composition (West Siberia, the Russian Federation), are given below. The objective of the study is to prove the fact that microorganisms are both an indicator of natural water condition and one of the factors, affecting on formation of their chemical composition.

2. Materials and methods

2.1. Subject of research

Microbiocoenosis of river waters in the Ob' basin in the section of its middle reach (figure 1) is the subject of research. The investigated area is located in forest part of physiographic West Siberia and in continental West-Siberian climatic region of temperate climatic zone. This area is mainly characterized by distribution of plain sub-taiga, mid and south taiga landscapes. The intense quantity of bogs which determines natural degree of flow control and high concentration of organic and biogenic substances in waters is the main feature of this area. Quite harsh weather conditions determine long winter season. During this period there is stable ice cover on rivers and the rivers are mainly fed by ground water. In spring snow melting results in heavy flood and, in turn, under plain relief it results in ordinary flooding and underflooding of a lot of areas. When the flood is going down



the erosion process intensity increases, and these processes have a very negative effect on economic entities and apartment houses. Therefore, Tomsk region's natural conditions, on the one hand, stimulate water resource formation, and, on the other hand, they determine unfavorable conditions of water use caused by low quality waters of boggy areas and necessity of considerable financial and material inputs to make arrangements for organizing flood-protection works and erosion control measures [1, 2].



Figure 1. Map of the studied area.

2.2. Sampling and research methods

The considerable part of material used in this paper, especially microelement, organic substance, microorganism content data, was obtained by authors in 1994 – 2014 yrs. This material was received due to field researches of Tomsk polytechnic university (TPU), Tomsk branch of the institute of petroleum geology and geophysics the Siberian Branch of Russian Academy of Sciences (SB RAS), Tomsk state university (TSU), Institute of water and ecology problem SB RAS, OJSC “Tomskgeomonitoring”, LLC “INGEOTEH”. And it was also obtained due to a number of researches, and surface-water body, water facilities monitoring in the territory of Siberian Federal District. According to working paper (WP) 52.24.353-94 “Recommendations. Sampling of land surface waters and treated sewerage” and GOST P 51592-2000 “Water. General requirements for sampling”, field works were carried out by conjugate geochemical testing of natural environment components according to WP 52.24.353-94 “Recommendations. Sampling of land surface waters and treated sewerage” and GOST P 51592-2000 “Water. General requirements for sampling”.

The field works included the reconnaissance study of the water body sites and surroundings which should be investigated, surface and underground water sampling, atmosphere precipitation, peat and bottom sediment sampling. If it is necessary, other environment components will be investigated and associated works will be carried out. Samplers or special containers were used for surface water sampling. The sampler was submerged at a depth of 0.3–0.5 m below surface. After reaching the required depth, the sampler was lifted to the surface and sample was poured in especially prepared containers made of chemically inert materials. To determine microelements, petroleum products, phenols, anionic surfactants, nitrogen compounds and phosphorus, the samples were preserved according to method of analysis. To carry out microbiological analysis, the water samples were taken without preservation in especially prepared glass containers. In transit and in the lab the samples were kept under conditions which excluded the possibility to contaminate them.

Methods of separation and interpretation of results are given in authors' and other researchers' publications [3–5].

3. Hydrochemical characteristic of river water

3.1. Microcomponents and pH

Large river waters of investigated area are at the average defined as low and mean mineralization freshwaters; they are also defined as hydro-carbonate calcium (according to classification by O.A. Alekhin), neutral and weakly alkaline ones. Minor and small river waters are characterized as from low to high mineralization freshwaters; in terms of pH, they range from weakly acidic to weakly alkaline ones. Main ions contents vary in a rather wide range, and they reach a maximum in south-western part of Tomsk region, in left-bank part of the Mid-Ob' basin, at the interface between a forest steppe zone and a south-taiga zone, which is in line with the Chaya and the Shegarka basins. There are the lowest and medium macro-component concentrations in river waters of right-bank taiga part of the Mid-Ob' basin, in the Tym and the Ket' drainage basins, and also in the Tom' basin (its upstream and midstream parts).

3.2. Dissolved organic substance

Both indirect indicators (chemical oxygen demand COD – indicator of resistant to oxidation substance content, 5-day biochemical oxygen demand BOD₅ – indicator of easily oxidizable substance content) and specific substance concentrations data were used to determine the level of organic substance contents. Total organic carbon in the region river waters is strongly varied a wide range from 3–4 mg/dm³ and less in the Tom' basin to 18–20 mg/dm³ and more in water of rivers of the Ob'- Irtysh interfluvium with waterlogged drainage basins.

The swamp area surface runoff which gives at an average over 17 000 tons of carbon of organic compounds per year is the most important source of resistant to oxidation organic substances according to COD. Sufficiently large concentrations of substances identified as hydrocarbons of the oil sequence are in waters of all investigated rivers. It can be associated with not only anthropogenic effect but specific natural conditions as well, for example, carbonaceous rock distribution in the Tom' basin [7, 8]. Swamps can be a source of hydrocarbon intake in river waters. It is confirmed by data of organic substance composition of peat and organic compound content findings in the immediate swamp waters [9]. Analysis of organic compounds brings us to the conclusion that there is predominance of odd carbon atom n-alkanes, and this clearly demonstrates their natural origin. In addition to hydrocarbons, a number of different organic compounds, including carboxylic acids, phthalates, chlorine-bearing substances, is found in river waters in Tomsk region.

3.3. Iron and biogenic substances (compounds of nitrogen, phosphorus and silicon)

As noted above, surface and subsurface runoff from swamps, containing a lot of organic substances, come into drainage network [10]. Organic substances in the swamp waters derive directly from the formation and evolution of swamps. Excessive moistening and low drainage conditions of watersheds, in turn, contribute to the swamps. Some of organic substances mineralize to form ammonia, and in aqueous medium they mineralize to form ammonium ions. If there is oxygen deficiency, nitrification process is less intensive, and it results in accumulation of ions NH₄⁺ and NO₂⁻ in swamp waters. Moreover, some organic acids (for example, fulvic acids) can form very stable iron, manganese and different metal compounds, accumulating in aqueous medium (mainly in the form of suspensions and colloids). As a result, the elevated concentrations of Fe, NH₄⁺ and rare NO₂⁻ are identified not only in swamp waters but in river waters as well. Moreover, amounts of them exceed specified water quality standards very often (with probability more than 20 %). Swamp waters are diluted and decomposed in more oxygen-rich medium (it concerns organic and biogenic substance contents) in the process of swamp water inflow in river net. Taking this into account, it seems clear that, as a rule, the content of iron, ammonium nitrogen, nitrite nitrogen and organic substances decreases in river waters.

3.4. Microelements

River waters of investigated area are characterized by extremely wide range of microelements variation. As a rule, well-defined regularities of spatial microelements distribution in river waters are not identified. Microelements content in waters were described in detail in papers [12, 13].

As compared with maximum permissible concentration for water in a river (MPCr) the contents of Cu, Mn, Zn and Al, and it is rare Hg, Mo, V, Sr, Ni are higher in Tomsk region's river waters, though Mn standard violations in the Ob' and its plain feeders with heavy swampy watersheds are defined more often than in the Tom'. The highest concentrations of Cd, Hg and Li are confined to the river Tom' and its feeders flowing in large industrial centers area [13; 1].

4. Results and discussion

4.1. Microbiological composition of river waters

Due to researches carried out in TPU and Tomsk branch of the institute of petroleum geology and geophysics SB RAS, the various groups of heterotroph and lithotroph microorganisms were identified in region river waters. They are 1) saprophytic bacteria, mineralizing dead organic material; 2) oligotrophic bacteria which are able to develop at low concentrations of organic substances; 3) chemo-organotrophic bacteria; 4) denitrifying bacteria which are able to reduce nitrates to gas; 5) nitrifying bacteria – autotrophic microorganisms receiving energy due to oxidation of deoxidized nitrogen compounds; 6) ammonifying bacteria, which can decompose complex nitrogen containing organic compounds (proteins, amino acids and a number of various substances), resulting in ammonia, hydrogen sulphide and carbon dioxide isolation; 7) thionic bacteria receiving energy due to oxidation of sulphur and its reduced compounds; 8) sulphate-reducing bacteria – anaerobic microorganisms which are able to reduce sulphates to sulphides when in use metabolism [3, 1]. Total characteristic of identified ecologo-trophic groups of microorganisms, contained in waters of the Ob' and its feeders, is placed in table 1.

Table 1. Average contents of certain groups of bacteria in waters of the Ob', the Tom' and their feeders.

Bacteria	Unit of measurement	The Ob'	The Tom'	Feeders of the Tom'	Plain feeders of the Ob'
Saprophytic	cell/ml	12131	12532	7576	21227
Oligotrophic	cell/ml	41891	37653	65096	33890
Thionic	number	4	6	2	0
Nitrifying	number	7	5	3	–
Denitrifying	number	9	10	10	12
Ammonifying	cell/ml	8646	4451	–	–
Sulfate-reducing	point	<1	1	0	–
Oxidizing:					
Heptane	c.u.	326	235	169	–
Octane	c.u.	332	279	300	–
Decane	c.u.	386	338	344	–
Phenol	c.u.	229	245	309	–
Number of samples		20	9–32	3–11	6

The obtained data analysis has shown that in the Ob' there is oligotrophic bacteria predominance in group composition of microorganisms adapted to scattered organic material uptake. At the average saprophytic bacteria concentrations are more than twofold lower than oligotrophic ones, and saprophytic and oligotrophic bacteria concentration ratio is known to decrease according to movement of water masses from South to North [3]. Thionic bacteria were noted to develop in the Ob' high and low of the Tom' mouth, and near the villages (Krivosheino, Molchanovo, Mogochino) in September, 1991[11]. Their presence and high intensity of evolution allow us to make an assumption that there were reduced

sulphur compounds in river waters in these sites. At the same period of time (September, 1991) thionic bacteria were not identified further northward, starting with the point located upwards of Kolpashevo (town). Their presence in the Ob waters, at least in 1991, is very likely to deal with inflow of the Tom' contaminated waters [3].

All in all, a decrease in the number of bacteria, which oxidize nitrogen containing organic substances, is observed northward. The similar tendency was not identified in the content change of other heterotrophic bacteria groups. As for hydrocarbon-oxidizing bacteria their total intensity of evolution in the Ob waters is mainly stable. The exception is provided by the special case of some points where the sharp increase of oil oxidizing bacteria (from 0...5000 cell/ml in the most of sections to 9000...28000 cell/ml downstream from the village Kargasok) was observed in summer 1999. Taking into account the fact that whole high concentration samples were selected at the river transport parking places or downstream from them, it may be concluded that there is pollution of the river waters with oil products, and it is anthropogenic pollution [3, 1].

Saprophytic microorganism contents mineralizing dead organic material are an average higher in waters of the Tom' than in the Ob', though their highest concentrations are identified not only in the sections of cities, which are potential microbiological pollution sources of water bodies (62000 cell/ml near Tomsk), but in Kemerovo region the river upwards from Mezhdurechensk (town) (69000 cell/ml 5 km upwards). In whole, bacterial contamination of the river is occasionally observed along the river.

Contrary to saprophytes, the level of oligotrophic bacteria content which are able to develop at low organic substance concentrations is higher in the Ob' but not in the Tom'.

Taking into account the fact that it is difficult for oligotrophic bacteria to develop in medium with increased concentration of nitrogen-containing organic compounds, it can be said that there are significant differences in qualitative composition of organic substances dissolved in waters of two rivers. Sulfate-reducing oxygen deficit bacteria should be noted among groups of microorganisms identified in waters of the river Tom'. Such kind of microorganisms in quantity 1 cell/ml were identified 0.3 km upwards Tomsk in March, 1998. In addition, it was noted that there were thionic bacteria in Kemerovo and Tomsk sections. This allowed us to make an assumption that there were reduced sulphur compounds in investigated river waters. Oil oxidizing bacteria contents in the Tom' waters as in the Ob' change slightly, and they account about 2000 cell/ml; this is in agreement with regular hydrocarbon distribution in river waters. Chemo-organotrophic bacteria distribution is characterized by a higher level of irregularity [3].

5. Conclusions

In general, according to microbiological indices waters of the Middle Ob' are characterized as contaminated. In accordance with requirements of GOST 17.1.2.04-77 "Indices of condition and assessment regulations of fishery water bodies" the category of saprobity vary greatly – from xenosaprobic ("clear") to polysaprobic ("dirty"). The worst condition is characteristic of minor rivers located in settlements or in the near vicinity of them. As for microbiological indices, the certain river water quality impairment is identified in sections of the river Tom', which are located within settlements or downstream from them, and sewage disposal of housing and utility companies.

Probably, considerable part of microorganisms, biogenic and organic substances, some microelements enter the region's rivers from natural and anthropogenic sources distributed in watersheds area. Swamps and wet parts of floodplains and valleys play an important role among natural sources; and as for anthropogenic sources, the main role belongs to the runoff from settlement and industrial areas. The purpose of microorganisms are also supposed to be the most important in the process of formation of nitrogen compound content and runoff; and to be of little importance when it deals with macroelements.

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