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Assessment of physical properties and pH of selected surface waters of the northern part of Western Siberia

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One of the undisputed natural resources of Western Siberia is a countless number of surface waters. They can be found in the form of all sorts of lakes from the smallest thermokarst ones of a surface area of only 1m^2 through large post-glacial lakes up to high-mountain lakes. To that large mires are to be added, acknowledged as the largest in the world. Other equally impressive forms of surface waters are countless streams and rivers with the Ob-river at the head, the eighth largest river of the world. All of that together is a tremendous challenge for research concerning ecology of these waters as only a few of them and only to a very limited degree have been the subject of scientific research.

Keywords: cloudiness of water, transparency, electrical conductivity, concentration of hydrogen ions (pH), concentration of oxygen and its saturation percent.

Introduction

Physical properties of water next to the chemical and biological properties are the base information necessary for honest assessment of quality of waters. Above all, they are a source of knowledge about living conditions of fauna and flora inhabiting a given type of surface waters. Since all waters are natural habitats just like soil for fauna and land flora, ability to correctly interpret the physical properties of water makes it possible to understand the essence of life processes which can be found in water bodies or watercourses. A special role of pH of water and the physical properties consists in the fact that these are able to be transformed suddenly and very quickly, even within a few days, and thus change the living conditions. For this reason, the most beneficial ecological conditions are found in waters with small fluctuations of physical parameters, as most of water organisms prefer water with pH 7 and well-oxygenated at the same time. On the contrary, sudden changes of pH and the physical parameters of water, as e.g.: decrease in its transparency or reduction in the oxygen content, considerably limit species diversity of organisms which can't live in such conditions. Therefore, changes of pH and the physical properties of water are the factor initiating usually a number of various changes in surface waters. Frequency and scope of changes of pH and physical properties of water depend to a large extent on weather conditions. This means that climate changes, as indicated by research of thermokarst lakes in Alaska, have influence on thermal conditions chemical composition and increase in biological activity [1]. This fact causes many consequences for waters, as e.g.: rapid development of phyto and zooplankton, excessive release of biogenic substances from the bottom deposits, occurrence of an oxygen deficit in demersal layers. Due to the above, one can boldly formulate a thesis that surface waters respond to the climatic changes most rapidly, especially of northern areas where chemical composition of waters is very poor due to which pace and scope of changes as regards the physical properties can run there the most rapidly.

Place and methods of research

This article demonstrates results of the research which was carried out between 21.08.2014 and 25.08.2014 in the permafrost zone within Nadym-Pur interfluve of Western Siberia. Earlier different features of this area were studied by the authors [2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13]. This research characterized by its complexity because it is a combination of physical, chemical and biological methods. Furthermore, through the planktonic netting 5 litres of water was filtered out of each water tested in order to determine the presence of zooplankton. Figure 1 shows places of research in spring 2013 and autumn 2014. This article in detail discusses results of the physical research and pH. Biological and chemical research have been demonstrated only partially insofar as they can contribute to better interpretation of the physical results. Detailed discussion of the biological and chemical results is planned in the next articles.

Research in 2014 covered:

- Sample 1 – a small watercourse a few kilometres in length located near the route from Novyy Urengoy to Pangody (group I)[1].
- Sample 2 – waters of a larger Pyakupur river in the place where it crosses the access road to Hanymey (group II)[1].
- Sample 3 – Waters of a larger Purpe river in the place where the river crosses the road linking the town of Purpe and Novyy Urengoy (group II)[1].
- Sample 4 – Waters of the Ob river in the middle of the route between the town of Kargasok and Strezhevoy (group III)[1].
- Sample 5 – Waters of a medium lake of approx. 50 hectares, located next to the road to the town of Hanymey, closed and not stocked with fry.
- Sample 6 – Waters of a medium lake of approx. 50 hectares, also located next to the road to the town of Hanymey, an open lake and stocked with fry.

[1] – In this work when discussing the results division of the rivers tested into III groups has been adopted. Small rivers with width of the channel at the place of research to 10 m (group I), medium rivers with width of the channel from 10 to 50 m (group II) and large rivers with width of more than 50 m (group III).

Equipment and analytical methods applied:

- Research of pH, conductivity, temperature and oxygen concentration and its saturation was carried out using a multifunctional instrument Multi 340i by WTW. Samples of water were analysed in a mobile laboratory within 2 hrs. since the sample has been taken. Analyses were carried out in the sample of water placed in a Winkler bottle with a funnel, standing in the magnetic mixer. The stirrer ensured even movement of water around the electrode. As a result, all research was carried out in identical conditions. Furthermore, the samples from all places were frozen and after two weeks unfrozen and tested at the same time using Multi 340i from the mobile laboratory and Multi 340i being a part of equipment of the TSU laboratory.

• Cloudiness research was carried out using a portable turbidimeter TRUB 355 IR by WTW. Water was analysed as in the previous case also in the mobile laboratory within 2 hrs. since the sample has been taken. Based on the cloudiness the transparency of water was calculated using the formulas.

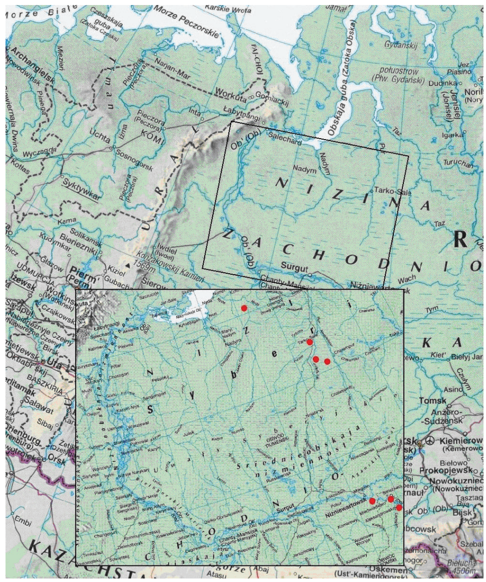

Fig. 1. Places of research

• Assessment of colour of water was made only visually and was used for guidance only.

Furthermore, a part of results of the physical research (oxygen, temperature) and pH was demonstrated which was carried out in the same area using the same equipment at the beginning of June 2013.

Test results

Table 1 demonstrates all results of the physical research obtained during autumn research in 2014. While, Table 2 compares average values from karst lakes of different size (from 1m^2 to 50 ha) tested in 2013 and a few rivers.

Table 1. Results of the autumn research in 2014

Parameter	Unit	Number of sample					
		1	2	3	4	5	6
Temperature	°C	14,5	15	15,1	14,1	17,6	16,3
pH[1]	–	6,5	7,5	7,3	8,5	8,2	8,6
pH[2]	–	6,3	7,3	7	8,5	7,0	7,6
Rodox	mV	– 153	– 162	– 144	– 169	– 161	– 162
Conductivity	nS	23	63	39	240	9	62
Oxygen	mg / dm^3	8,2	10	8,7	10	13,3	13,2
Oxygen	%	82,5	99,5	87,8	97	137,5	136
Turbidity	NTU	3,2	9,8	9,9	15,2	1,6	3
Transparency[3]	cm	281	91	90,9	60	560	300

[1] – pH measurement made in the mobile laboratory
[2] – pH measurement made after the sample has been unfrozen in the TSU laboratory
[3] – value calculated using the formula P = 900 / M, where P – transparency of water in cm, M – cloudiness of water mg / dm^3 according to [14]

Supplementary data on properties of the waters tested and on their environment:

• Sample 1. A flow of water in the watercourse minimal, only 1/3 part of the river channel occupied (1m), fish occurring in small numbers, water transparent, straw-coloured.

• Sample 2. A flow of water in the river low, the whole channel filled with water, fish and zooplankton occurring in large numbers. The water contained plenty of suspended matter, colour of water light brown typical of peat waters.

• Sample 3. Exactly as sample 2.

• Sample 4. A flow of water also minimal, mineral and organic suspended matter in large numbers, colour of water natural to slightly straw-coloured, phyto and zooplankton occurring in large numbers.

• Sample 5. Closed drainage lake I located in a permafrost area, on the peat base, a part of the bottom was sandy only in a few places. Despite the peat base and drainage area water in the lake was unusually transparent, of a natural colour, with zooplankton occurring in large numbers and probably the lake devoid of fish.

• Sample 6. Open lake II located at a distance of 5 km to north-west from the previous one, also on the peat base with muddy parts of the bank and bottom in large numbers. Colour of water lightly dark brown caused by the presence of humic compounds. The lake inhabited by quite large numbers of phyto and zooplankton as well as fish and waterfowl.

Table 2. Results of the spring research in 2013

Parameter	Unit	Number of sample					
		1	2	3	4	5	6
Temperature	°C	9,8	11,3	14,2	13,9	7,2	12
pH	–	5,2	6,4	8,1	7,4	4,3	6,0
Redox	mV	64	0	–10	50	105	18
Conductivity	nS	13	29	347	110	15,9	18
Oxygen	mg / dm^3	7,8	6,6	5,3	5,4	8,4	6,6
Oxygen	%	82	76	67	69	72	67

Sample 1 – a small watercourse a few metres in width, side stream of the lake II, stocked with fry,

Sample 2 - the Pyakupur river, drawing in the place as in 2014,

Sample 3 the Shagarka river (side stream of the Ob river),

Sample 4 - the Ob river (average value of five samples taken from Strezhevoy up to the height of Tomsk,

Sample 5 - average value of 50 karst lakes,

Sample 6 – waters of the post-glacial lake.

Discussion

Surface waters reaction of our globe is the most often found between 6.5 – 8.5 and only a few waters are more acidified to pH 4 or are more basic with their pH reaching values to 9 [3]. The above-mentioned statement given in specialist literature from the 1980 is nowadays difficult to be considered fully true. Probably, in this assessment no surface waters were taken into consideration of the northern part Siberia occurring in great numbers. It is possibly related with the fact that waters of this part of the Asian continent are very little known and thus they could not be taken into consideration by the author in the general assessment of acidity of waters. It can be assumed that if quantity and acidity of waters of Siberia was well known, then the opinion on pH of surface waters of the Earth would be different. To that more and more frequently occurring cases of acidification of waters as a result of acid rain which are to be added occurring the most intensively in Scandinavia, an eastern part of the United States and Canada [15].

Waters reaction results demonstrated in Table 1 and 2 provide a cross section of all types of surface waters which can be found in the area of Western Siberia analysed. Due to the fact that the number of results is small, very general assessment of acidity of waters was made. Yet, above all, the results obtained form a base to propose many theses which will be thoroughly analysed within the next two years during planned further research. Due to the diversity of waters analysed, their general assessment of acidity has been adopted in this article with regard to the 4th category, i.e. small rivers (sample 1 (table 1 and 2), medium rivers (sample 2 and 3 table 1 and 2 table 2), large rivers (sample 4 table 1 and 3 and 4 table 2) and lakes (sample 5 and 6 table 1 and 2). The following observations result from the results analysis for particular categories:

Acidification of water in rivers is dependent on their size. From the data obtained, both spring (table 2), and autumn (table 1), directly proportional dependence results which is demonstrated on Figure 2. The results obtained very clearly indicate a broad difference of pH of water in rivers from very acid through inert to basic in connection with their size

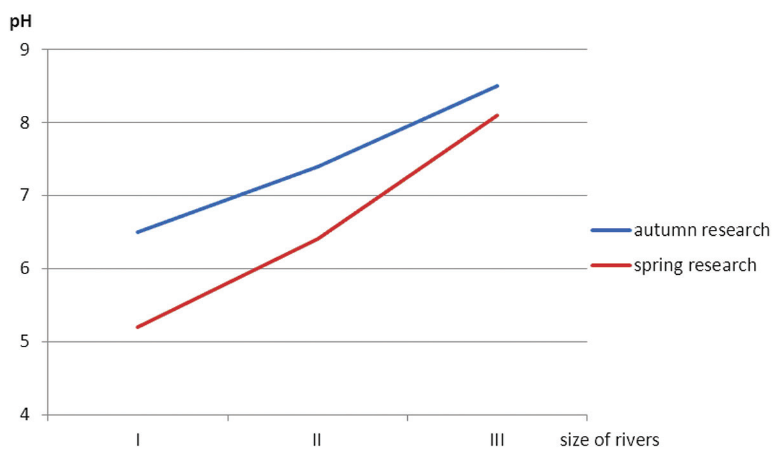

Figure 2. A variability graph of pH of river waters in relation to the division of waters analysed into III groups adopted in this publication.

In the case of lake waters a significant difference in acidity of water occurred during the period of research. The spring results unambiguously indicate strong acidification of lake waters (average of pH of 4.3) which is typical of lakes located in areas of tundra and wooden tundra. Inert, and even basic nature of lake waters is in autumn great and unexpected surprise. However, it is not certain whether such results are a consequence of permanent change of pH in waters which in autumn lose its acidity, or it was only a momentary result related to e.g.: current weather situation. The research results of thermokarst lakes in Alaska also indicate the presence of seasonal changes to pH from acid in early summer to 7.45 in August [16].

Analyses of acidity of water carried out within up to two hours since samples have been taken in the mobile laboratory conditions indicate slightly greater pH values than the same samples which were taken, frozen and then analysed in the university laboratory. It needs to be added that as it was already mentioned earlier, in the mobile laboratory, all samples were measured in the same conditions. It was held on the magnetic stirrer in the Wrinkler bottle closed using a special funnel which prevents the air from getting inside, and the carbon dioxide from getting out from the bottle. Whereas, samples tested in the university laboratory were poured two times and were in the liquid state a few hours before they were frozen and after they had been unfrozen.

Based on the observations and the physical research results demonstrated theses can be drawn explaining changeable conditions of acidity of waters in the area analysed.

First thesis – dependence between the size of a river, and its acidity is connected with insolation of water and activity of phytoplankton. Water in small rivers is mostly well overshadowed by a number of trees growing on the banks. In larger rivers the number of sun-warmed areas increases, and in large rivers overshadowed areas constitute a very small part. The more the water is sun-warmed, the more intensely the phytoplankton comes into bloom which consumes free carbon dioxide contained in water and, consequently, water becomes more basic. The thesis of intensive development of the phytoplankton is confirmed by the cloudiness research of water which, as shown in Figure 3, indicates direct dependence of the cloudiness on the size of a river. Guidance research of the phyto and zooplankton content carried out additionally in rivers analysed confirms increase in the number of organisms together with increase in the size of a river. In order to confirm the thesis proposed detailed research needs to be carried out in different seasons and in various insolation conditions, including the chlorophyll research.

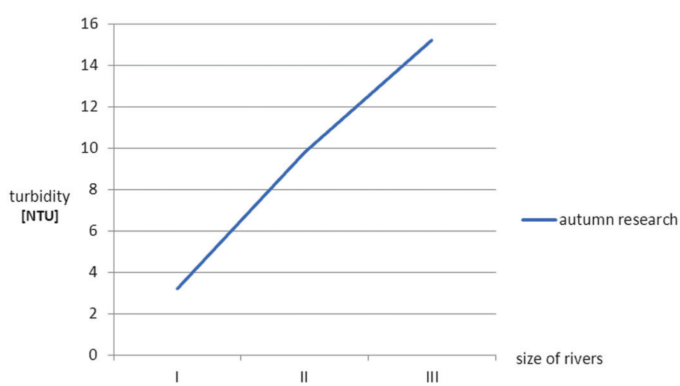

Figure 3. A variability graph of cloudiness of river waters in relation to the division of waters analysed into groups adopted in this publication.

Second thesis – significantly greater fluctuations of water acidity in lakes as compared to rivers are a result of poorer mineral composition of these waters. Comparing conductivity values in lakes analysed (except for the sample 6 table 1) to waters of rivers analysed one can clearly see that the lake waters as compared to the river ones, in particular to the largest rivers, are very poor. Conductivity results obtained for the lakes analysed range from 9 to 18 µS. These are the values which can be found in pure rainwater. It makes these waters, and also rainwater, be very soft, and minor changes in e.g.: carbon dioxide concentration in water cause rapid increase or reduction in acidity of water [17]. Higher conductivity content in the lake sample No. 6 is caused by the fact that in this lake fish occurs in large numbers which automatically leads to increase in fertility of water and a number of mineral substances.

Third thesis – found seasonal changes in acidity of water from pH 4.3 to 8.6 are a direct result of activity of water microorganisms. Usually, the type of the base which can be found in the drainage area of waters have direct influence on acidity of surface waters. This is also why in the case of Western Siberia peat nature of this area makes that waters which can be found here are generally acid. Yet seasonal loss of acidity (increase of pH up to value of 8.6) is caused by changes in both activity of the bacteria decomposing the biomass, and of the phytoplankton producing the biomass. Biochemical decomposition of organic substances involves releasing free carbon dioxide to water, while the photosynthesis process of the phytoplankton leads to its consumption. As a result of these changes acidification increases - when the amount of carbon dioxide increases, and acidification decreases - when the amount of carbon dioxide decreases. Results of the BOD_5 research carried out in autumn proves existing high biochemical activity of the bacteria, in particular in lake waters. In the case of both lakes analysed the BOD_5 value ranged from 5.4 mg O_2/dm^3 for the first lake (sample No. 5 table 1) to 5.7 mg O_2/dm^3 for the second lake (sample No. 6, table 1). Especially in the case of the first lake it is high value because all other analysed parameters of this body of water indicated oligotrophic nature of the lake, while only the BOD_5 parameter indicated higher class from mesotrophic to eutrophic. The results obtained unambiguously indicate intensive decomposition of organic matter in waters of the lakes analysed. This fact is confirmed by results of the oxygen concentration research. Perfect oxygen conditions (concentration of approximately 13 mgO_2/dm^3) in both lakes. Furthermore, unusually high temperature of approximately 17 degrees (as for the area of tundra and wooden tundra) prevailed in both lakes which was in favour of the bacteria decomposing the organic matter. On the other hand, results of the analysis of oxygen concentration in lakes and approximate assessment of the presence of the phyto and the zooplankton indicated even greater activity of the phyto and the zooplankton. It is directly confirmed by the fact that in both lakes saturation of water with oxygen amounted to respectively 136 and 137%. These values clearly indicate that the photosynthesis process was much more intensive than the mineralisation process. It should be remembered that mineralisation involves consuming the oxygen which leads to reduction in its concentration. In the case of lakes analysed production pace of the oxygen during the algae photosynthesis was considerably higher than pace of its consumption by the bacteria. High activity of the phytoplankton in autumn is confirmed by results of the oxygen saturation in lakes from the period of spring where waters of 50 lakes analysed did not indicate such a high oxygen saturation as in the period of autumn research. Average value of saturation was only 72%, and for the post-glacial lake only 67% (Table 2). Also, saturation of water with oxygen in rivers is definitely higher in autumn which proves increase in intensity of the photosynthesis as compared to spring. Summing up the above discussion the following thesis can be finally accepted. In surface waters of the northern part of Western Siberia acid by nature and poor in mineral substances major changes of pH of water and its physical properties occur from spring to autumn. Increased activity of water microorganisms is the reason, in particular of the phytoplankton and the bacteria which trigger off increase or decrease of the carbon dioxide concentration. Changes triggered off as regards concentration of this gas in combination with a small number of carbonates and hydrogencarbonates which can be found in waters lead to increase in pH of water in the case the carbon dioxide concentration decreases and decrease in pH of water in the case the carbon dioxide concentration increases. Also, this thesis can be confirmed by results of the thermokarst lakes tests in Alaska, where daily changes in pH reaching even up to 0.5 were observed [16]. Such rapid changes can only be caused by sudden blossoming of the phytoplankton. In order to unambiguously confirm the fourth thesis a full series of tests needs to be carried out throughout at least one year (as described in the article), supplemented with analysis of the carbon dioxide content in water and analysis of the chlorophyll a content. These tests need to be carried out in summer, autumn, winter and spring, and they need to be monitored non-stop throughout a week in the course of each series.

Fourth thesis – found large fluctuations of pH of surface waters must cause in organisms inhabiting these waters significantly greater ability to tolerate pH than in organisms inhabiting more stable waters. In the case of waters analysed it concerns lakes and small as well as partially medium rivers. Large rivers as shown by the tests carried out due to a significantly richer mineral composition, and hence higher content of carbonates and hydrogencarbonates react to concentration changes of the carbon dioxide caused by biological activity of microorganisms significantly weaker. It can be said that acid waters have been able to be found in the given area incessantly since the last glaciation ceased. As a result, water organisms could for millennia well adapt to live in acid environment. For example, in Europe acid waters have generally occurred at the beginning of the 20th century, their number and the level of acidification have been constantly growing. In this case, acidified waters have become the main cause of total extinction of fish population in many parts of Europe, and in Scandinavia in the first place [18]. On the whole, acidification reduces diversity of species of water flora, although as shown by a part of tests some insects were able to live in water with pH of 3.5 [19]. While in the area analysed despite similar acidification fish can be still found in all rivers analysed and in some lakes. It concerns open and deeper lakes which do not freeze in winter. Planktonic tests carried out in autumn proved existence of a wide range zooplankton in all types of waters analysed. An interesting result was analysis of water from the first lake (sample 5 table 1) where high concentration of microscopic forms of zooplankton was found, almost imperceptible to the naked eye. During the autumn tests neither thorough quantitative, nor qualitative analysis of the zooplankton was carried out. Despite that, based on comparison of an amount of organisms found and taking into consideration extreme values of pH which can be found, and poor composition of waters, the approximate results obtained were impressive and proved rich biological life in the waters analysed. As in the previous cases the thesis proposed is based on first initial yet complex tests. In order to confirm it subsequent series of tests need to be carried out, including precise quantitative and qualitative analysis of both the phyto-, and the zooplankton, and also analysis of composition of benthic organisms.

Summary

Carrying out complex tests covering physical properties of waters, their chemical composition and partial biological analysis gave a much wider view on ecology of the surface waters of Western Siberia. The results obtained despite a tiny amount and short implementation period of the tests indicated many interesting dependencies and properties which can be found in the waters analysed. The main result of the tests carried out is formulation of four theses which in the next two years will be able to be verified. They concern:

First thesis – of an occurring dependency between the size of rivers, and their acidity caused by insolation of water and activity of the phytoplankton.

Second thesis – of influence of mineral composition of lake and river waters on the size of fluctuations of water acidity.

Third thesis – of influence of microorganisms activity on the size of changes in pH of water under the influence of changes in the carbon dioxide concentration.

Fourth thesis – of existing tolerance of living water organisms to extreme values of pH of water.

Furthermore, the tests carried out, and the general assessment of the results made indicated how poorly waters of Siberia are known and how many secrets hide in them. Particularly valuable fact is that the vast majority of waters of this area do not show any significant anthropogenic changes, which makes them unique in the whole world.

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