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SOME PHYSICO-CHEMICAL FEATURES OF WATER IN SUPRAPERMAFROST ZONE IN THE HORNSUND REGION (SW SPITSBERGEN)

WYBRANE WŁAŚCIWOŚCI FIZYKOCHEMICZNE WÓD WARSTWY AKTYWNEJ WIELOLETNIEJ ZMARZLINY W REJONIE HORNSUNDU (SW SPITSBERGEN)

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Abstract. The hydrogeochemical background of electrolytical conductivity (36–188 µS/cm) and pH (from 6.23 to 7.35) of groundwater occurred in active layer of permafrost in the Hornsund region (SW Spitsbergen) was determined based on data collected in summer season of 2005. The shallow zone of water circulation (supramermafrost zone) in Arctic regions results during intensive melting of snow, glaciers and top layer of permafrost in short Arctic summer periods. Water was sampled from ephemeral springs occurred at the foot of the mountain range slopes in the margin zone of coastal lowlands of the Greenland Sea. Anomalous zones, outside the ranges of maximum EC and pH, mainly coincide with the occurrence of birds colonies.

Key words: water chemistry, suprapermafrost zone, Hornsund region, Spitsbergen.

Abstrakt. Tło hydrogeochemiczne przewodności elektrolitycznej właściwej (36–188 µS/cm) i odczynu pH (6,23–7,35) wód podziemnych warstwy aktywnej wieloletniej zmarzliny w rejonie Hornsundu (SW Spitsbergen) określono na podstawie badań przeprowadzonych w sezonie letnim 2005 roku. Opróbowaniem hydrochemicznym objęto okresowe źródła, tworzące się u podnóży stoków górskich w pasie wybrzeża Morza Grenlandzkiego. Drenują one strefę płytkiego, przypowierzchniowego przepływu wód (supramermafrostu) w warstwie aktywnej wieloletniej zmarzliny, tworzącej się w wyniku intensywnego topnienia jej górnych partii oraz śniegu i lodowców w okresie arktycznego lata. Strefy anomalne, przekraczające maksymalne wartości zakresu PEW i pH, pokrywają się z miejscami bytowania kolonii ptaków.

Słowa kluczowe: chemizm wód, warstwa aktywna wieloletniej zmarzliny, rejon Hornsundu, Spitsbergen.

INTRODUCTION

In polar regions during the short Arctic summer takes place an intensive melting of snow, glaciers and the top layer of permafrost resulting in surface and subsurface water circulation. The subsurface circulation of groundwater occur in the shallow zone related to active layer limited from the bottom by permafrost. Among the three zones of groundwater circulation, distinguished in polar areas, it is the shallowest one called suprapermafrost zone (Haldorsen, Heim, 1999). In the area of south-western Spitsbergen, drained by ephemeral springs and streams flowing directly to the Greenland Sea, some hydrogeochemical studies were carried out during the summer season of 2005 in the frame of the 18th scientific expedition of the Wrocław University. The study area includes the coast of the Greenland Sea between the Hornsund

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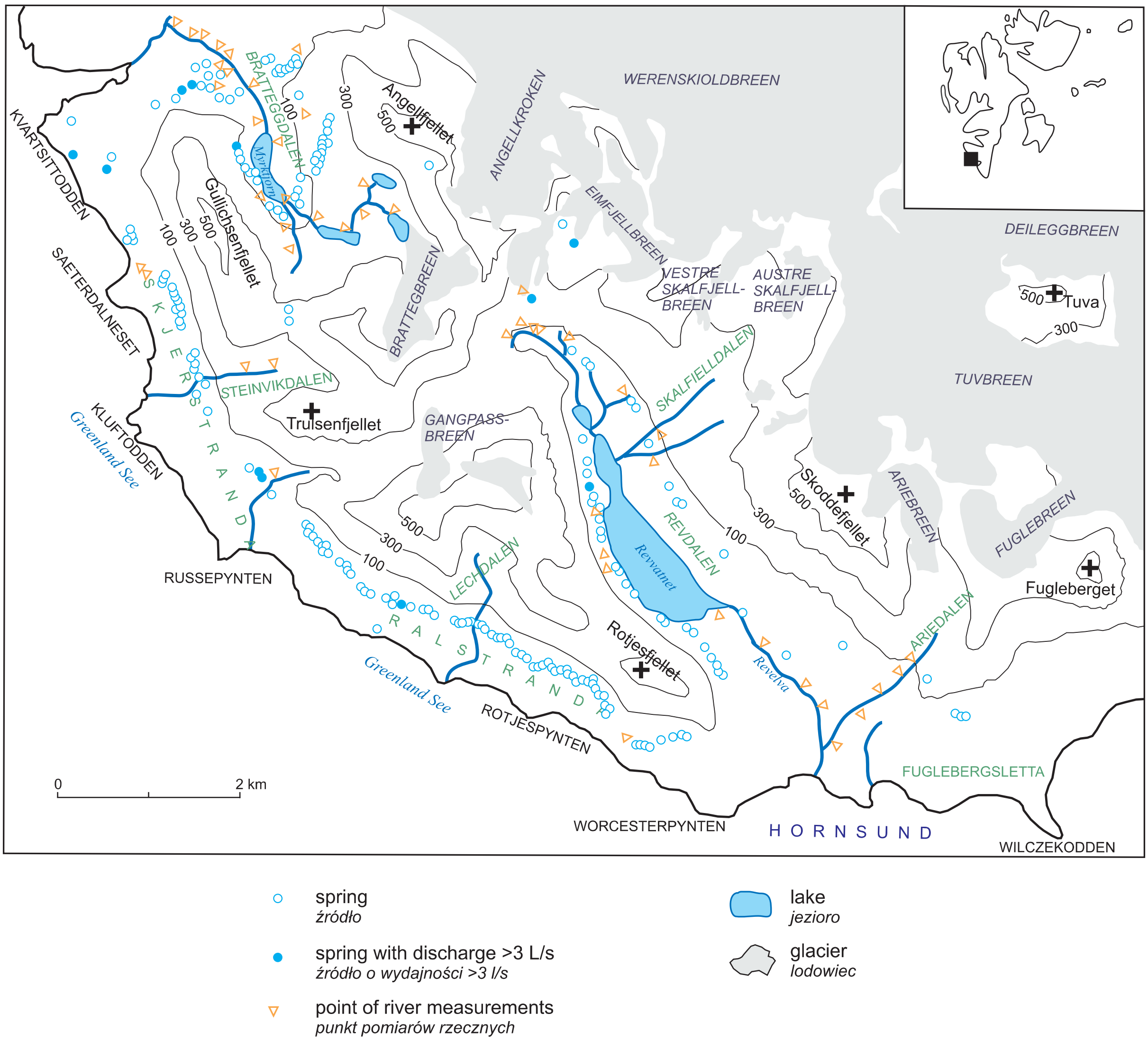

Fig. 1. Map of the study area with location of measuring points

Mapa obszaru badań z lokalizacją punktów pomiarowych

fjord and the Werenskiold glacier with two catchments: the Brattegg River in the northern part and the Revelva River in the south (Fig. 1). The paper presents the results of some hydrogeochemical studies which are complementary to other information about water chemistry of Svalbard (i.a. Bieroński, 1977; Krzyszowska, 1985; Krawczyk, 1992; Haldorsen, Lauritzen, 1995; Haldorsen, 1996; Pulina *et al.*, 1999; Cooper *et al.*, 2002; Olichwer *et al.*, 2013). Investigations were focused especially on temperature, electrical conductivity and pH of groundwater in suprapermafrost zone.

GEOLOGICAL BACKGROUND

Geologically, the discussed part of Spitsbergen is built of Proterozoic crystalline rocks (Bratteggdalen, Gulliksenfjellet, Skoddefjelet, Arienkammen and Revdalen formations), that in the coastal zone and in river valleys are covered by Quaternary clastic formations. The crystalline bedrock is formed of various kinds of metamorphic rocks, mainly gneisses, mica-schists, quartzites, amphibolites, migmatites, marbles and calcareous-silicate rocks (Manecki *et al.*, 1993). The rocks are characterised by a varied degree of fissuring and a high degree of weathering in the upper parts of the profile. The thickness of weathered covers increases down the slope. The river valleys are filled with coarse clastic material, interdigitating with moraine formations of local glaciers. The coastal zone is covered by coarse gravels and boulders, forming a system of coastal terraces.

METHODS

The investigations, included surface waters of glacial rivers and smaller streams, and springs which are numerous in the tundra zone, were carried out in the period of July-August 2005. Physico-chemical features of water as temperature (T), electrical conductivity (EC) and pH were measured in situ during field works in respectively for: 193 (T), 172 (EC) and 129 (pH) points using calibrated WTW 340 multiparametric meter. Precision of measurements was and 0.1°C for temperature, 0.01μS/cm for EC and 0.01 for pH. Temperature of the Brattegg and Revelva rivers were measured during summer seasons of 2005–2007. In the Brattegg River catchment 6 water samples were taken for detailed chemical analysis as well. They were filtered through a nitrocellulose membrane of 0.45 μm. Besides the basic ionic composition, also nitrogen compounds (NO_3, NO_2, NH_4) and phosphates were determined using atomic adsorption spectrometry (AAS) method with graphite tray. Colorimetric titration with HCl was used for alkalinity determination.

PHYSICO-CHEMICAL FEATURES OF WATER IN SUPRAPERMAFROST ZONE – RESULTS AND DISSCUSSION

The occurrence of groundwaters in the studied area is mainly associated with the upper part of permafrost which thaws during the Arctic summer (suprapermafrost zone). In the so called active layer of permafrost with the thickness varying from a few dozen centimetres to *ca.* 2.1 m (Migała, 1994), the basic part of total drainage is formed. The water-bearing rock is built of coarse fluvial, glacial and marine deposits, as well as weathering regolits of metamoprhic rock, covering the fissured crystalline bedrock. The floor of this zone is determined by the upper limit of permafrost whose thickness in the area of Svalbard is estimated as 100–400 m (Haldorsen, Heim, 1999). The thick layer of permafrost effectively limits recharge of the deeper water-bearing zones. Shallow groundwaters, located within the active layer, are mainly recharged by glacial ablation and thaw waters. A considerable part in recharge comes also from mel-

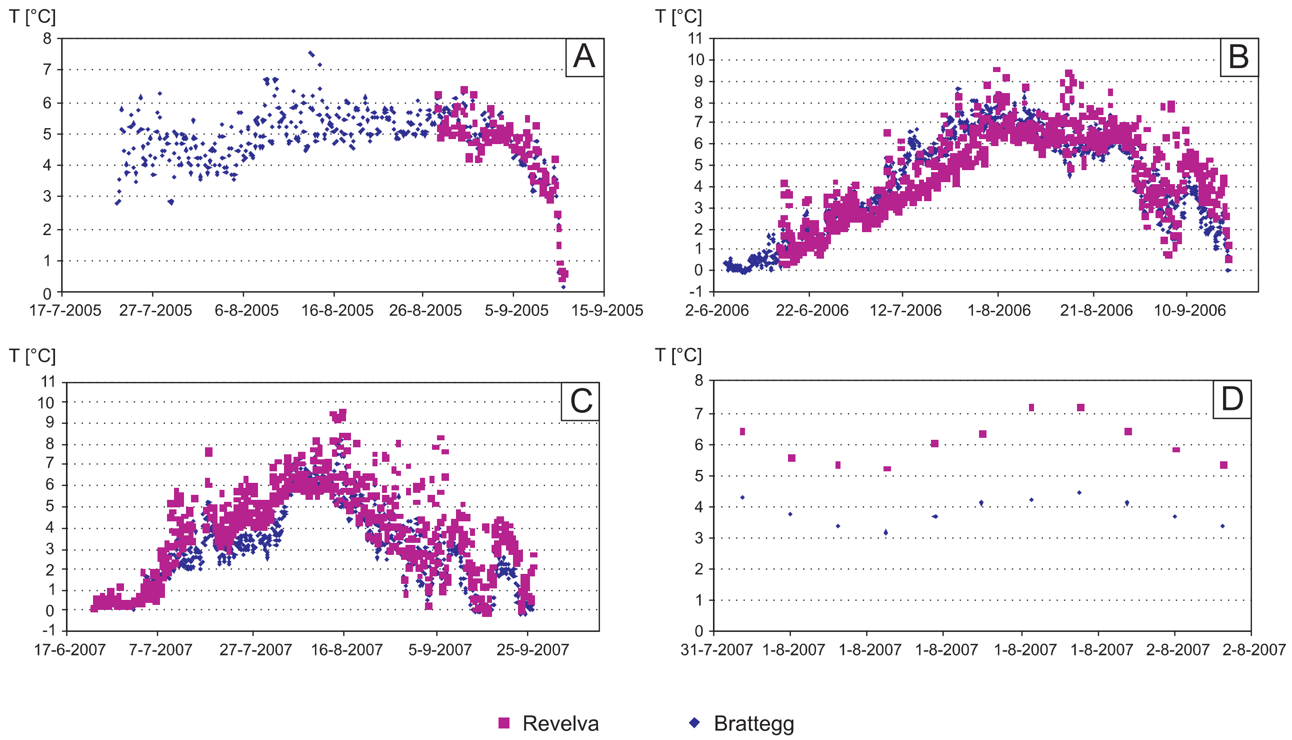

Fig. 2. Temperature of Revelva and Brattegg river water during the summer polar season of 2005–2007 (A, B, C) with daily variation (D)

Temperatura wód rzeki Revelvy i Bratteggi w okresie lata polarnego 2005–2007 (**A**, **B**, **C**) wraz z dobowymi zmianami (**D**)

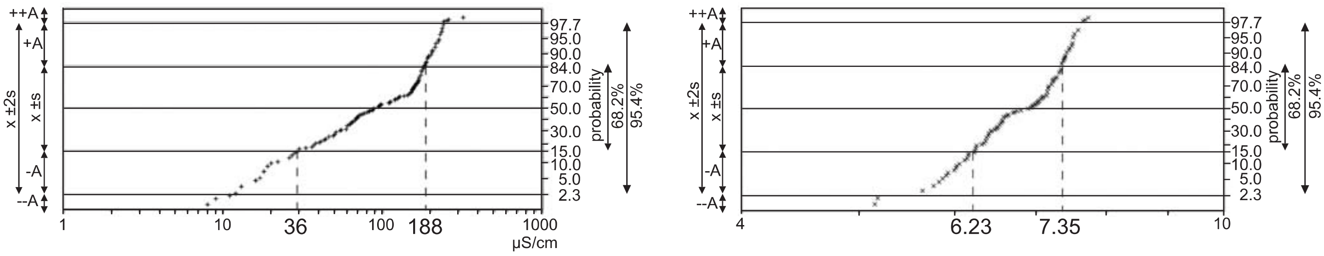

Fig. 3. Hydrogeochemical background of electrolytical conductivity and water reaction pH

Tło hydrogeochemiczne przewodności elektrolitycznej właściwej i odczynu pH wód

ting of the upper layers of permafrost and from rains which are frequnt during the summer. In study area the mean annual sum of atmospheric precipitation is 422 mm (Kwaczyński, 2003). The drainage of active layer is mainly in the form of numerous ephemeral springs occurring at the foot of mountain massifs, in the lowland of both, the coastal belt and the river valleys.

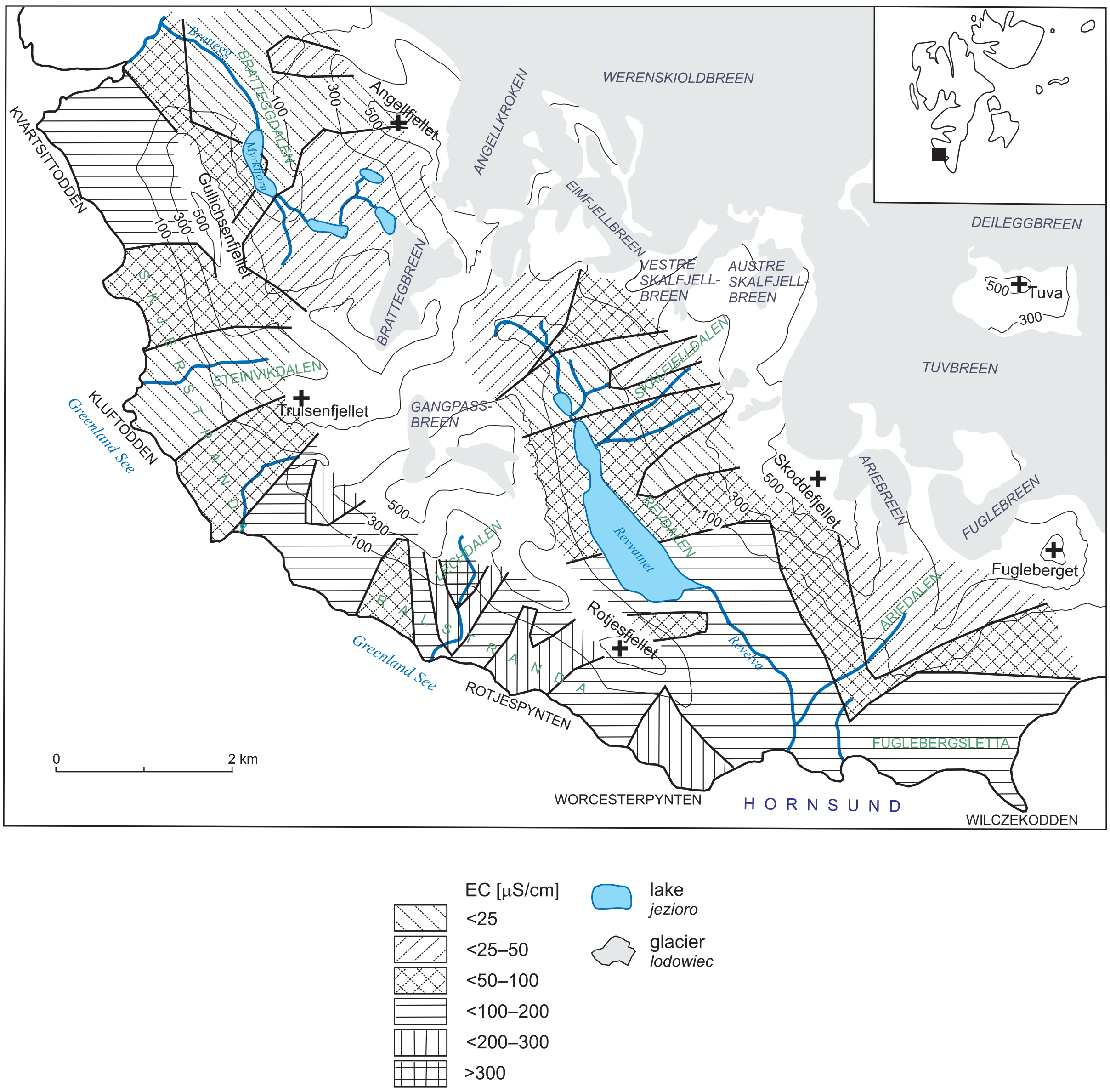

Fig. 4. Spatial distribution of water electrolytical conductivity

Rozkład przestrzenny przewodności elektrolitycznej właściwej wód

A concentration of water outflows is observed along morphological egdes (Fig. 1). Point outflows in the form of typical descending springs are the most common. During the field investigations a total of 209 springs were mapped, with a varied discharge of 0.06 L/s to 10.4 L/s (the mean value was 0.86 L/s).

The groundwater runoff forming in the active zone depends both on air temperature which determines the level of glacial ablation, and on atmospheric precipitation. Changes in air temperature affecting the thermal regime of the glaciers and permafrost are reflected in the thermal regime of the waters. In the study period July–August of 2005 the temperature of the waters ranged 0.1–8.9°C, the mean value being 1.8°C. The lowest values were observed in outflows recharged by waters of thawing snow-ice patches, the highest – for stagnant waters in the form of ponds in small depressions. The thermal regime of the Revelva and Brattegg rivers is similar and varies from ca. 0 to nearly 9,6°C. Water runoff of the rivers starts at the turn of May and June with the water temperature close to 0°C. From that moment it gradualy increases to 6°C and sometimes over 8°C till the end of August (Fig. 2A, B, C). In August the ice cover dissapears completely from the lakes located in the upper sections of the rivers. At the beginning of September the water temperaure starts to decrease gradually to 3–4°C, and about half of September it rapidly drops within a few days to nearly 0°C, till the flow in the rivers stops completely. Daily amplitude of water temperature in both rivers is 1.5–2.0°C (Fig. 2D).

The short period of water residence time in rock environment results in a low mineralisation. The waters are characterised by a wide range of electrolytical conductivity values, from 8 to 319 μS/cm. The mean value for the 172 measured points is 108 μS/cm. The hydrogeochemical background value for electrolytical conductivity ranges from 36 to 188 μS/cm (Fig. 3).

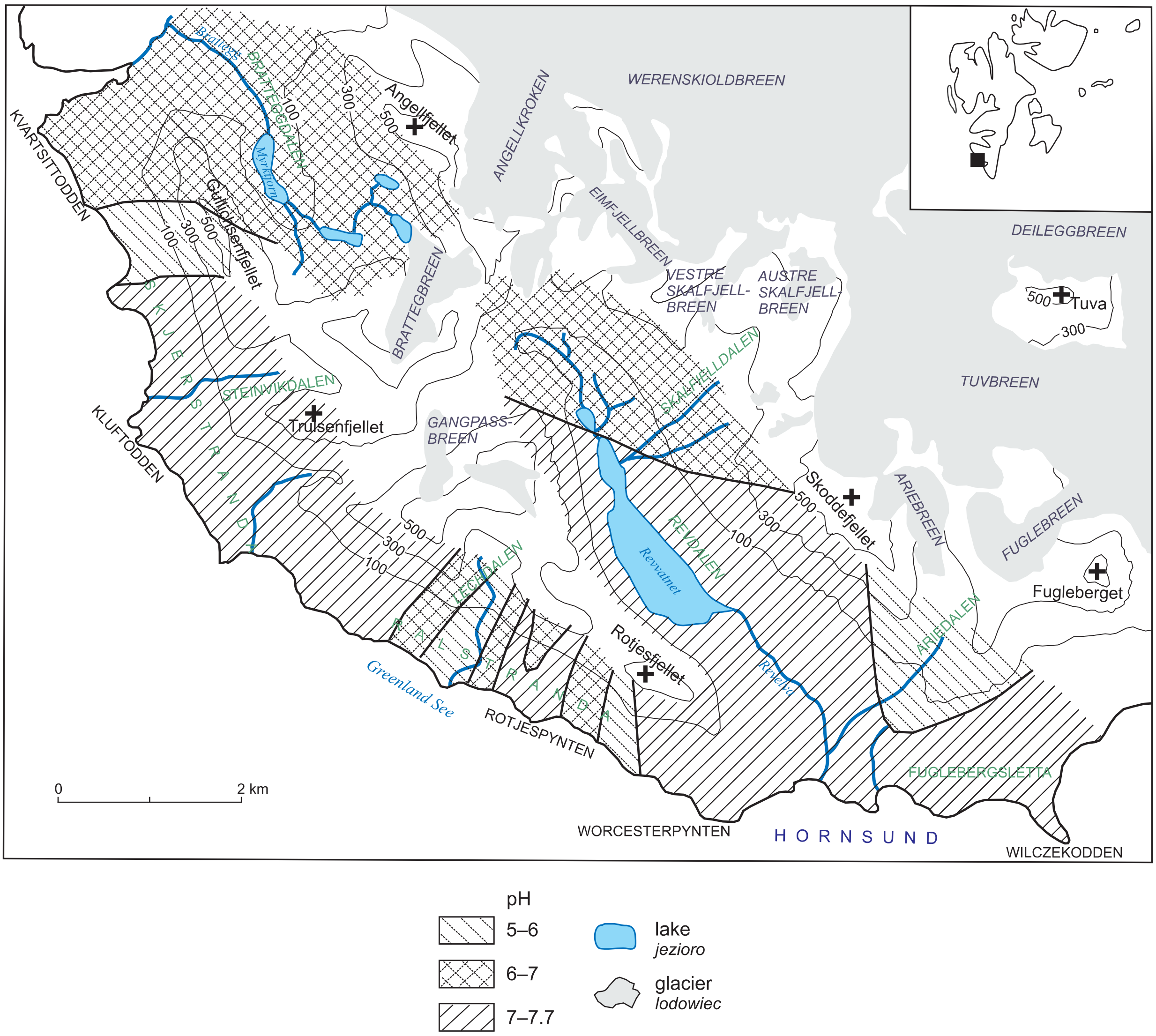

Fig. 5. Spatial distribution of water reaction pH

Rozkład przestrzenny pH wody

Table 1

Chemical composition of water in active laser of permafrost in the Brattegg river catchment

Skład chemiczny wód warstwy aktywnej w zlewni potoku Brattegg

Range of concentration	EC	pH	Ca	Mg	Na	K	HCO_3	SO_4	Cl	NO_3	NO_2	NH_4	PO_4
	μS/cm	mg/L											
	8-94	5,92–6,75	1,4–8,1	1,4–6,1	2,2–3,9	0,2–0,77	15,6–47,3	1,6–10,3	1,5–4,0	0,11–1,25	0,008–0,031	0–0,09	0–0,04

The highest conductivity values (over 200 μS/cm) were recorded at the foot of SW slopes of the Torbjörnsenfjellet and in the coastal belt of Rålstranda. Higher values of EC were measured in waters in the areas harbouring bird colonies. The lowest values were recorded in the upper parts of the valleys: Ariedalen, Revdalen, Bratteggdalen, where the measuring points were located near the melting glacier (Fig. 4).

The waters of the studied area are characterised by pH values from 5.15 to 7.73, with the mean value of being 6.8. The hydrogeochemical background value for pH is within 6.23–7.35 (Fig. 3). In most of the waters pH corresponds to the background ranges determined for this parameter. Lower values were recorded in the region of western slopes of the Gulliksenfjellet, southern slopes of the Rotjesfjellet and the upper part of Ariedalen (Fig. 5).

Water of permafrost active layer has a low mineralization and a slightly acidic to slightly alkaline pH value. A small amount of dissolved solids is the result of a short residence time of water, flowing quickly through relatively well-permeable rock environment. Then, a concentration of dissolved solids is mainly determined by the chemical composition of water recharging the active layer, including the chemistry of permafrost, glaciers, precipitations, soils and upper parts of fluvial and marine sediments or weathered rocks as well. Compared with other factors the geological structure of the studied area does not affect physico-chemical characteristics of the waters of the active layer in any significant way. Only the occurrences of calcite marbles of Ariekammen Formation in the vicinity of Rotjestfjellet can rise the value of EC and pH of waters (Fig. 4, 5). An important biotic factor contributing to the increase of waters mineralization and pH is bird droppings. In the area of bird colonies, mainly in the vicinity of Torbjörnsenfjellet and in the coastal belt, the increase in EC and pH is observed (Fig. 4, 5). A similar increase in water mineralization, explained by the increase of nitrogen and phosphates were found in the Fugleberget and Gulliksenfjellet areas, where birds colonies cause the enrichment of waters with the nutrients, fertilizing the environment (Krzyszowska, 1985). In the Gulliksenfjellet area the phosphate concentrations were up to 13 mg/L, nitrate nitrogen – up to 7.2 mg/L and TDS reached above 130 mg/L. HCO_3^- and Ca^{2+} ions predominate in the ionic composition of waters (Krzyszowska, 1985). However, due to their low mineralization even low concentrations of chloride (up to 5.25 mg/L) can change the hydrochemical type of water for HCO_3-Cl-Ca (Bieroński, 1977; Krzyszowska, 1985). Such a type of water was determined in the area of Bratteggdale (Bieroński, 1977). Investigations carried out by the authors in the Brattegg River catchment during the summer of 2005 not confirmed a significant share of chlorides in the chemical composition of water. Water of suprapermafrost zone in this catchment represents two main chemical types: HCO_3-Mg-Ca and HCO_3-Ca-Mg. So, such ions as HCO_3^-, Ca^{2+} and Mg^{2+} are the dominant basic ions in their composition. The content of main ions, apart from the bicarbonate and sulphates, does not exceed 10 mg/L (Tab. 1). Low chloride concentrations reaching 4 mg/L indicate a weak effect of aerosols deriving from sea waters. Likewise, no significant concentrations of nitrogen compounds were found. The maximum content of nitrates reaches 1.25 mg/L. Trace quantities of phosphates in the waters indicate a negligible effect of biotic factors on their chemical composition. In fact, no abundant bird populations were observed there. Such a chemical composition is typical for groundwaters in the subsurface active zone of permafrost, with a rapid turnover and residence time in the rock environment.

CONCLUSIONS

Groundwaters of suprapermafrost zone in the Hornsund region has low mineralisation (EC hydrogeochemical background ranges 36–188 μS/cm) and slightly acidic to alkaline pH (6.23–7.35). The geological structure of the studied area does not affect physico-chemical characteristics of waters in active layer of permafrost in any significant way in contrast to biotic factors. Anomalous zones, outside the ranges of maximum EC and pH, mainly coincide with the occurrence of birds colonies and calcite marbles of Ariekammen Formation.

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STRESZCZENIE

W pasie wybrzeża Morza Grenlandzkiego pomiędzy fiordem Hornsund a lodowcem Werenskiolda w sezonie letnim 2005 r. dokonano oceny właściwości fizykochemicznych wód podziemnych, formowanych w warstwie aktywnej permafrostu. W trakcie prac terenowych wykartowano 209 źródeł, charakteryzujących się zmienną wydajnością od 0,06 do 10,4 l/s. Wyznaczono tło hydrogeochemiczne przewodności elektrolitycznej właściwej (36–188 µS/cm) i odczynu pH (6,23–7,35) wód źródeł. Wykazano również ich zmienność przestrzenną w całym analizowanym obszarze, stwierdzając najwyższe ich wartości przekraczające górną granicę tła w strefach bytowania kolonii ptaków.