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ORIGINAL PAPER Accepted:

HYDROLOGICAL AND CHEMICAL WATER REGIME IN THE CATCHMENTS OF BYSTRA AND SUCHA WODA, IN THE TATRA NATIONAL PARK

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ABSTRACT

The chemical composition of surface water and groundwater is subject to constant changes, which result primarily from meteorological factors (for instance, size and intensity of atmospheric precipitation), hydrological factors (for instance, the degree of hydration of the mountain massif and changes in river flows), and geological-lithological factors (the type of bedrock). The aim of the present research was to examine the hydrological and chemical regime of surface and underground waters in the Bystra and Sucha Woda mountain stream catchments.

Between December 2013 and December 2016, 77 series of measurements were collected at the rhythm of twice a month (n = 611 water samples) from 8 sites, which represented both surface waters (watercourses, ponds) and underground waters (karst springs). The studied area possesses very distinct geological duality. The southern part is a crystalline region, and the northern part is made up of sedimentary rocks. During the field studies, the following have been measured: water levels of the watercourses, flow rates, and physicochemical characteristics of water, such as electrical conductivity, pH and water temperature. At the same time, water samples were collected for laboratory analyses, which included general mineralization and concentrations of Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, SO_4^{2-}, Cl^{-}, NH_4^{+}, PO_4^{3-}, NO_3^{-}, Li^{+}, Br^{-} i F^{-} ions.

The geological structure had the greatest impact on the chemical composition of waters in the Bystra stream and Sucha Woda stream catchments. The waters representing the crystalline region were characterized by significantly lower total mineralization, lower specific electrical conductivity, and lower ion concentration than water in the crystalline-sedimentary (karst) region. The average value of total mineralization in the crystalline region was 14.3 mg · dm^{-3}, and in the crystalline-sedimentary region – 81.2 mg · dm^{-3}. The waters in the crystalline region were characterized by a demonstrably lower pH (average pH of 6.5) than the water in the karst region (average pH of 7.7).

Low values of mineralization, electrical conductivity and concentration of main ions were accompanied by increased flows during the summer and autumn. In all the waters subjected to testing, there was also a marked decrease in the value of these parameters during the spring thaw. In the feeding of streams and karst springs during this time, slightly mineralized melt-waters had their significant share. In spring, there was also the greatest variation in the chemical composition of the studied waters. This variability was clearly lower in the lower Bystra karst spring than in the Goryczkowa karst string. It was most likely related to a different rate of melt-water inflow to the two karst springs. In all the tested waters, the highest values of total mineralization, electrical conductivity and concentration of main ions occurred during the winter low discharge, which resulted from the predominance of underground feed in the river's runoff. In all the studied waters, a clear decrease in NO_3^{-} concentration was observed during the summer and autumn months. Most probably, this was associated with increased NO_3^{-} uptake by plants during the growing season. In the waters of streams draining the crystalline part of the Bystra stream catchment there was clearly lower nitrate concentration than in the Bystra stream waters draining the crystalline-sedimentary (karst) part. The chemical

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composition of the Bystra stream water, draining the crystalline-sedimentary (karst) part of the catchment, was strictly dependent on the chemical composition of groundwater from the Goryczkowy and lower Bystra karst springs.

Keywords: Tatras, water chemistry, nutrients, high mountains

INTRODUCTION

The chemical composition of river waters is primarily determined by the geological structure of the catchment (Johnson et al. 1969 Rice, Bricker 1995, Cameron 1996, Burns et al. 1998). Hydro-meteorological conditions, such as the total amount and distribution of atmospheric precipitation during the year, as well as the seasonal dynamics of river runoff, also play an important role (Feller, Kimmins 1979; Hem 1989; Bhangu, Whitfield 1997; Żelazny, Siwek 2012). The important role of substrate rocks (bedrock) in shaping the chemical composition of waters in the Tatra mountains was indicated by, among others, Oleksynowa and Komornicki (1996) and D. Małecka (1989). This results in the zonation of the chemical composition of waters in the Tatra mountains (Żelazny 2012).

Małecka (1989) and Barczyk (2008) also drew attention to the important role of the water circulation rate and the size of the feeding zones, in particular in the case of karst springs, which generally also drain areas outside the home catchment. Investigations of seasonal changes in ion concentration in Tatra karst springs included the Chochołowskie and Lodowe Źródło karst springs (Wolanin, Żelazny, 2010) and the Olczyskie karst spring (Wójcik, 2012). Due to the occurrence of complicated karst systems and numerous karst springs, the Bystra stream catchment area has been an area of numerous studies in the field of hydrogeology (Barczyk, 2008; Wit, Ziemońska, 1960; Małecka, 1997) and hydrochemistry (Oleksynowa, Komornicki 1990, Żelazny 2012).

The circulation of ions in the catchment is a topic that is discussed in the literature. Detailed studies on the circulation of calcium, nitrogen, sulphur and phosphorus were conducted in the Hubbard Brook catchment in the White Mountains in the USA by Likens and Bormann (1995), and in several forested catchments in the Catskill Mountains (USA) by Murdoch and Stoddard (1992).

The aforementioned studies indicate that NO_3 concentrations in flowing waters are closely related to the course of the growing season in the given catchment (Johnson et al. 1969 Betton et al. 1991; Reynolds et al. 1992; Lepistö 1995; Arheimer et al. 1996; Bhangu, Whitfield 1997; Miller, Hirst 1998; Holloway, Dahlgren 2001; Sullivan, Drever 2001; Clark et al. 2004). According to Lovett et al. (2005), also the change in chloride concentration in river waters during the year is related to the growing season and to summer absorption of chlorides by the root system of trees. Some authors argue, like Lynch and Corbett (1989), that the changes in the concentration of nitrogen and sulphur compounds in river waters are associated with variable atmospheric deposition of these compounds during the year. Likens et al. (1967) and Siwek (2012) also indicated high seasonal variation of potassium, whose concentration was lower in the summer (vegetative) period than in winter.

The aim of the research was to learn about the hydrological and chemical regime of surface and groundwater in the Bystra and Sucha Woda streams' catchments.

STUDY AREA

The research was carried out in the Bystra stream catchment located on the border between the Western and the High Tatras (Kondracki, 2002) and on the Hala Gąsienicowa in the Sucha Woda Valley. The highest point of the area is Kondracka Kopa (2004 m above sea level). The catchment is enclosed in a hydrometric section at 955 m above sea level. The average slope is 26.8°C (Żelazny, 2012). The catchment of Bystra stream is characterized by a complex geological structure. The southern part of the area is made up of crystalline rocks, mainly from granite and granodiorite rocks, and from metamorphic rocks. The northern part is built of sedimentary rocks that undergo strong karst processes. These are mainly limestones and dolomites, as well as conglomerates, quartz sandstones, shales and marls. The bottom of the Bystra valley and of Hala Gąsienicowa is lined with rock waste sediments from the Holocene and Pleistocene period (Piotrowska et al., 2015). The southern part of the Bystra stream catchment is cut by a system of valleys, which have undergone a strong transformation in the Pleistocene under the impact of the glacier (Klimaszewski, 1988). The central and northern part is a trough valley, which in the lower course had been extended by the proglacial waters. The studied area is characterized by the presence of vegetation and climatic zones (Hess, 1996). The average gradient of temperature drop is 0.5°C per every 100m. The lowest parts are located in the lower montane zone (up to 1200 m above sea level), where spruce plays the most important role; the central part of the Bystra stream catchment is located in the upper montane zone (up to 1550 m above sea level) dominated by spruce forest; the upper parts are located in the subalpine zone with the predominance of mountain pine (up to 1800 m above sea level); and the highest in the alpine zone (over 1800 m above sea level), where alpine grasslands occur (Mirkowa-Piękoś, 1996). The annual total amount of rainfall increases with altitude, and in the highest parts, it can reach 2000 mm (Hess, 1996). Snowfall has a significant share in the structure of precipitation. Different types of soils were formed in the studied catchments (Skiba et al., 2015). In the southern part of the catchment, these are mainly raw-humus rankers, podzolic soils, and raw debris soil. There are podzols occurring on the moraine sediments. On the sedimentary rocks, there are different types of rendzinas (proper redzina, faw debris soils, raw-humus rankers, brown soils, brown pararendzinas). In the central and northern part of the catchment, at the bottom of the valley and in the lower parts of the slopes, there are also dystrophic brown soils, as well as eutrophic brown soils and brown alluvial soils.

METHODS

The research was carried out from December 2013 to December 2016 and it included the sampling of surface waters (streams, ponds) and underground waters (karst springs) in the Bystra stream catchment and on the Hala Gąsienicowa in the Sucha Woda catchment. Water samples were collected in disposable polyethylene bottles at 8 measuring points (see: Figure 1, Table 1)

A total of 77 measurement series were taken at the rhythm of twice a month (n = 611 water samples). At two measuring points, the temperature was also measured (every day at 7:00 a.m.) as well as the flow rate at the time of water sampling (in points 7 and 2). Determination of concentrations of Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, SO_4^{2-}, Cl^{-} i NO_3^{-} ions in the water was

Table 1. Characteristics of the sampling points

Number of point in the map	Name	Longitude	Latitude	Height above sea level [m a. s. l.]	Part of the catchment
1	Bystra stream – dam next to Nosal	19.98216	49.27704	955	Crystalline sedimentary
2	Bystra stream below the karst springs	19.97205	49.25875	1150	Crystalline sedimentary
3	Lower Bystra karst spring	19.96850	49.25527	1170	Crystalline sedimentary
4	Bystra stream above the karst springs	19.96839	49.25466	1170	Crystalline sedimentary
5	Goryczkowe karst spring	19.97246	49.25435	1201	Crystalline sedimentary
6	Goryczkowy stream	19.96834	49.24541	1325	Crystalline
7	Niżnia Goryczkowa Rówień watercourse	19.96818	49.24497	1327	Crystalline
8	Zielony Staw (pond)	19.99770	49.22930	1675	Crystalline

Source: Own study based on data

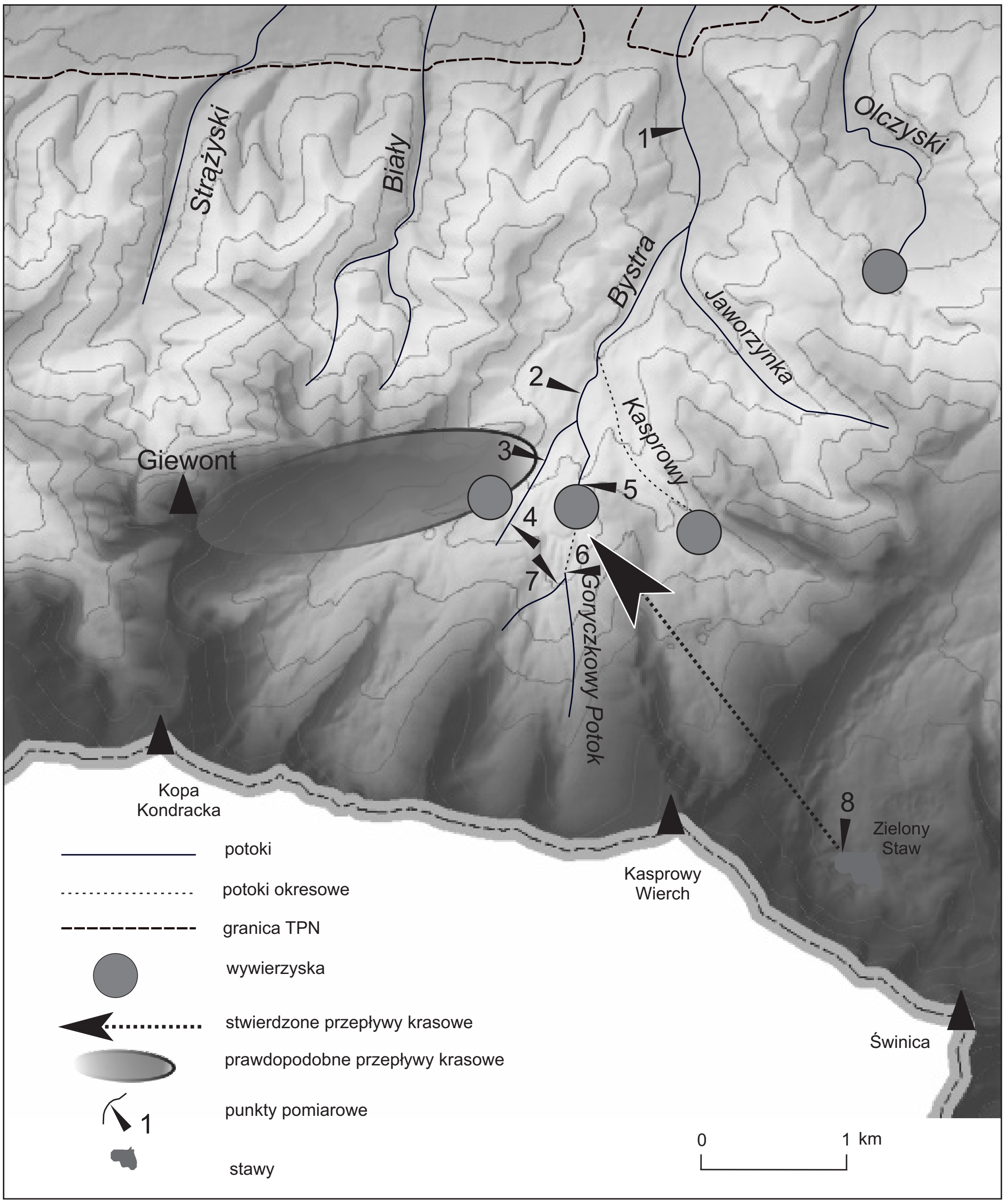

Fig. 1. Bystra stream – location of the sampling points

Source: Own study

performed by means ion chromatography, using a DIONEX ICS-2000 chromatograph. The sum of all the determined ions, for the purpose of further analyses, is understood as mineralization. Statistical analyses were performed using the Statistica 13.1 software. The Piper diagram, made using the Grapher 13 software, was used for the analyses. In order to analyse the hydrological and chemical regime, the year was divided into four parts corresponding to the main seasons: spring, summer, autumn and winter.

RESULTS AND DISCUSSION

The waters representing the crystalline areas were characterized by a much lower mineralization, lower conductivity, and lower concentration of the majority of the main ions than the waters representing the crystalline-sedimentary (karst) areas. For example, the waters of Goryczkowy Potok (stream), draining the crystalline part of the catchment, were characterized by average mineralization of 12.9 mg · dm^{-3} (see: Table 2), whereas the waters of Bystra stream below the inflow of the Goryczkowy and lower Bystra karst springs had six times higher average mineralization, namely 83.4 mg · dm^{-3} According to Oleksynowa and Komornicki (1996) and Żelazny (2012), such a large difference is related to the geological structure of this area: streams and springs draining the crystalline part have little possibility of leaching the weakly soluble granitoid and metamorphic rocks, unlike the streams and springs that drain sedimentary areas, mainly made of karst limestone, dolomite and shale. The waters in the crystalline region were characterized by a clearly lower pH (average pH of 6.5 pH) than the water in the karst region (average pH of 7.7 pH).

Furthermore, waters flowing from the crystalline part of the Bystra stream catchment were characterized by a lower proportion of Ca^{2+} and HCO_3^- in their chemical composition than the streams and karst springs of the crystalline-sedimentary part (see: Figure 2). This is associated with a very high content of calcite ($CaCO_3$) and dolomite ($CaMg[CO_3]_2$) in sedimentary deposits, and their negligible content in crystalline formations (Gaweł 1959). The streams that drain the crystalline part were characterized by a higher proportion of Na^+ and K^+ in their chemical composition, which results from the relatively high content of sodium compounds (plagioclase, for example, albite $Na(AlSi_3O_8)$) and potassium (orthoclase $K[AlSi_3O_8]$, muscovite $KAl_2[AlSi_3O_{10}(OH)_2]$, and biotite $K[AlSi_3O_{10}(OH)_2]$ in crystalline rocks (Gaweł 1959). The waters of Ziuelony Staw (pond) are characterized by low mineralization (see: Table 2), similar to the waters from the southern part of the Bystra Valley. They differ in terms of a higher calcium content and lower content of magnesium, sodium and potassium among cations (see: Figure 2).

The chemical composition of the studied waters was subject to changes throughout the year. These changes clearly referred to changes in flows. The average flow rate in the stream representing the crystalline catchment was 9.8 $dm^3 \cdot s^{-1}$, and the coefficient of variation was 98%. In the Bystra stream, draining the crystalline-sedimentary basin, the average flow rate was 832 $dm^3 \cdot s^{-1}$, and the coefficient of variation was 55%. The stream draining the crystalline catchment exhibits almost double variability of flow throughout the year (for Niżnia Goryczkowa Rówień

Table 2. Average values of ion concentrations in the sampling points.

Point number		1	2	3	4	5	6	7	8
Mineralisation	mg ·dm^{-3}	106.90	83.38	93.97	42.69	78.79	12.94	14.91	14.89
Ca^{2+}		18.79	15.43	17.03	7.97	14.84	1.89	2.30	3.09
Mg^{2+}		4.50	3.11	3.65	1.24	2.89	0.45	0.53	0.21
Na^+		0.89	0.89	0.88	1.08	0.90	1.00	1.04	0.47
K^+		0.41	0.36	0.37	0.33	0.36	0.21	0.24	0.21
HCO_3^-		73.31	54.79	64.80	26.43	49.87	5.71	6.68	8.12
SO_4^{2-}		6.73	6.70	5.07	3.87	7.75	2.49	2.74	1.55
Cl^-		0.43	0.32	0.32	0.40	0.32	0.22	0.23	0.21
NO_3^-		1.76	1.72	1.77	1.31	1.76	0.91	1.08	0.96

Source: Own study based on data

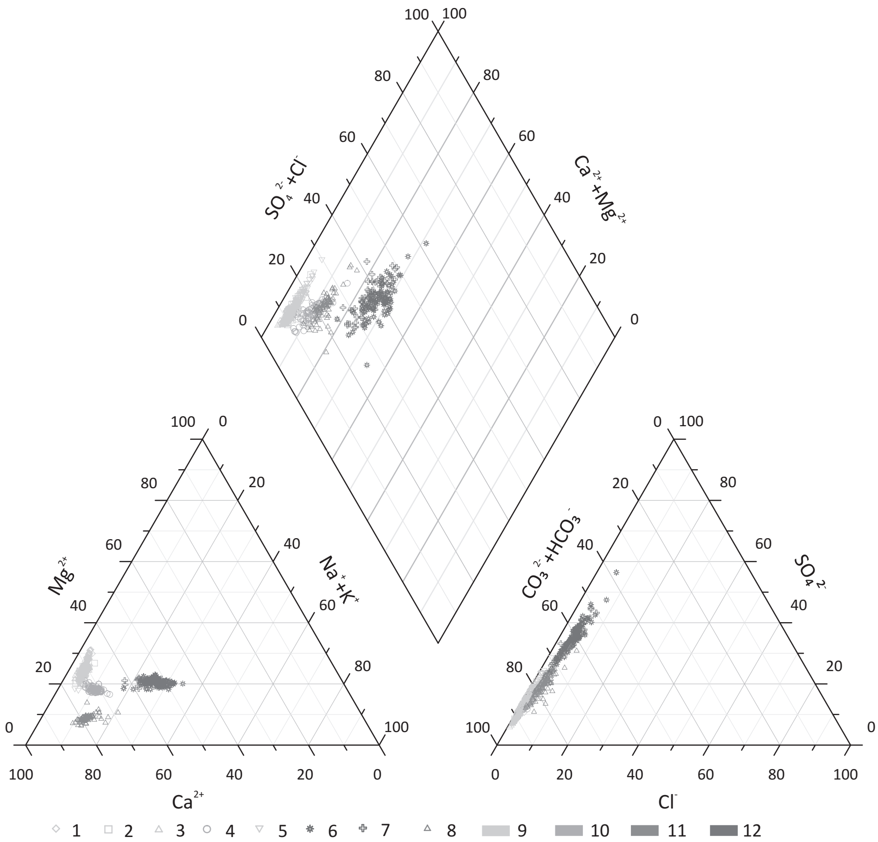

Fig. 2. The proportion of main ions in water. 1. Bystra stream – dam net to Nosal, 2. Bystra stream below the karst springs 3. Lower Bystra karst spring, 4. Bystra stream above the karst springs, 5. Goryczkowe karst spring, 6. Goryczkowy stream 7. Niżnia Goryczkowa Rówień watercourse, 8. Zielony Staw (pond), 9. Karst part of the catchment, 10. Crystalline-sedimentary part of the catchment, 11. Crystalline part with the dominance of granitoid rocks, 12. Crystalline part with the dominance of metamorphic rocks.

Source: Own study based on data

watercourse, cv = 111.8%, for Bystra stream below the karst springs, *cv* = 54.2%), while 84 times less its value (Sajdak, 2017). This results from the much smaller catchment area, and probably the much faster circulation of water in crystalline rocks, due to the lack of resource-rich reservoirs capable of water retention (Wit, Ziemońska, 1960). The lowest flow rates are observed in the winter months, when most of the water is stored in the snow cover, whereas high rates are observed in summer and autumn when there is heavy rainfall (see: Figure 3). In the spring period, higher flow rates appear, which are caused by thaws. The lowest water temperatures are recorded in winter, and the highest in summer (see: Figure 3). A similar dependence on the seasons can be observed in the Bystra stream in the crystalline-sedimentary part, however, due to the fact that the flow in the stream is shaped by the karst springs, temperature fluctuations are much smaller than in the crystalline part.

The waters of streams draining both the crystalline and the crystalline-sedimentary part of the Bystra stream catchment exhibited significantly lower mineralization, lower conductivity and lower main ion concentrations in summer and autumn than in spring and winter. Lower values of the analysed physicochemical parameters accompanied increased water levels during the summer and autumn. Low-mineralized rainwater entering the streams caused the dilution of the

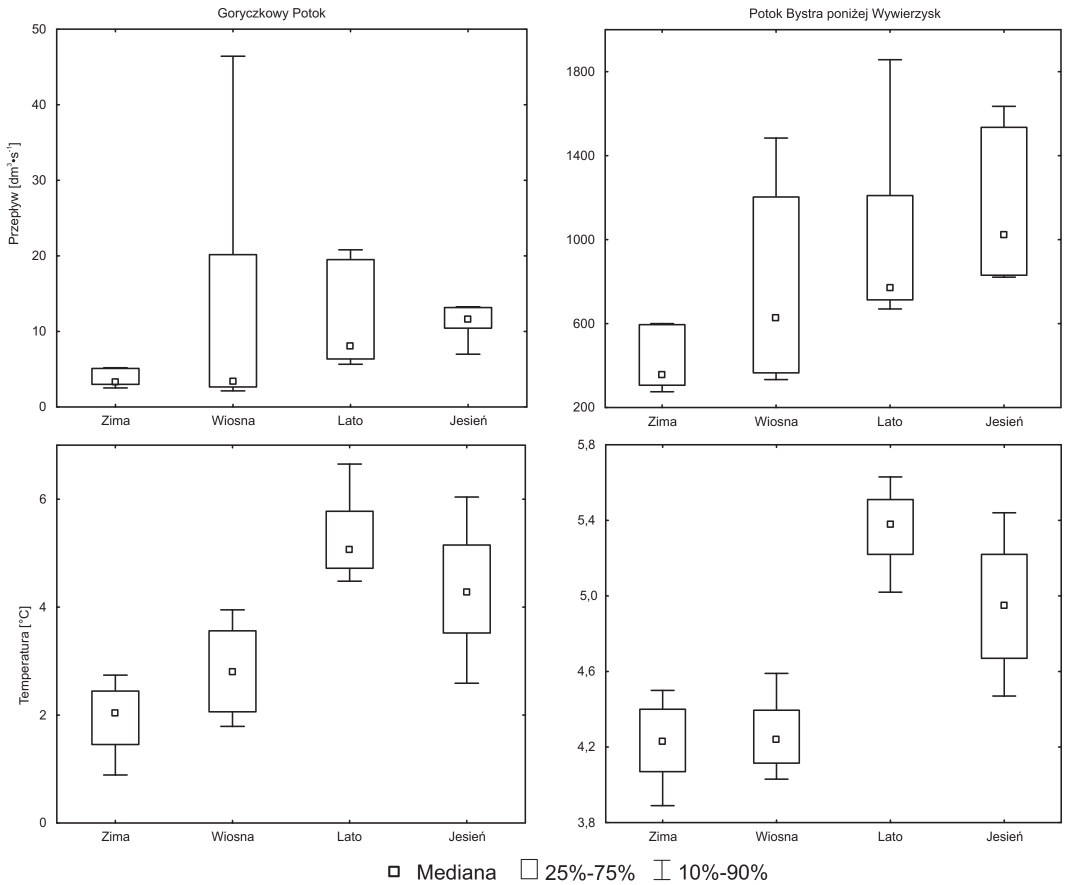

Fig. 3. Variability of water flow and water temperature in respective seasons, in the stream draining the crystalline part of the catchment (Niżnia Goryczkowa Rówień watercourse) and the crystalline-sedimentary part of the studied catchment (Bystra stream below the karst springs).

Source: Own study based on data

highly mineralized groundwater constantly feeding the streams. In the winter and early spring, the streams were supplied almost exclusively with groundwater, as the water from precipitation was stored in the snow cover. In the late spring, the snow cover was melting and releasing the water "trapped" in it. The low mineralized water from snow melting reached the streams and diluted their waters. Therefore, the greatest differences in the mineralization, conductivity and concentration of most major ions occurred in the spring. This is evidenced by the higher quartile distances of the tested parameters in the spring than in the other seasons (see: Figure 4 and Figure 5). The phenomenon of dilution of stream water in periods of elevated water levels is a common phenomenon, and as such it is often described in the literature (for instance, Cameron 1996; Bhangu, Whitfield 1997; Muscutt, Whithers, 1996; Drużkowski 1998; Pekarova et al. 1999; Żelazny, Siwek 2011). In the majority of the tested waters, there was a higher share of SO_4 and Cl^- in their chemical composition during spring and winter than during summer and autumn. Explanation of this phenomenon requires further research (see: Figure 6).

In the Goryczkowe karst spring, the lowest mineralization, lowest conductivity and lowest concentration of the majority of main ions occurred usually in the summer, and in the lower Bystra karst spring, in the autumn. Clearly higher values of these parameters occurred in spring and winter. In Goryczkowe karst spring, similarly to the drainage streams of both

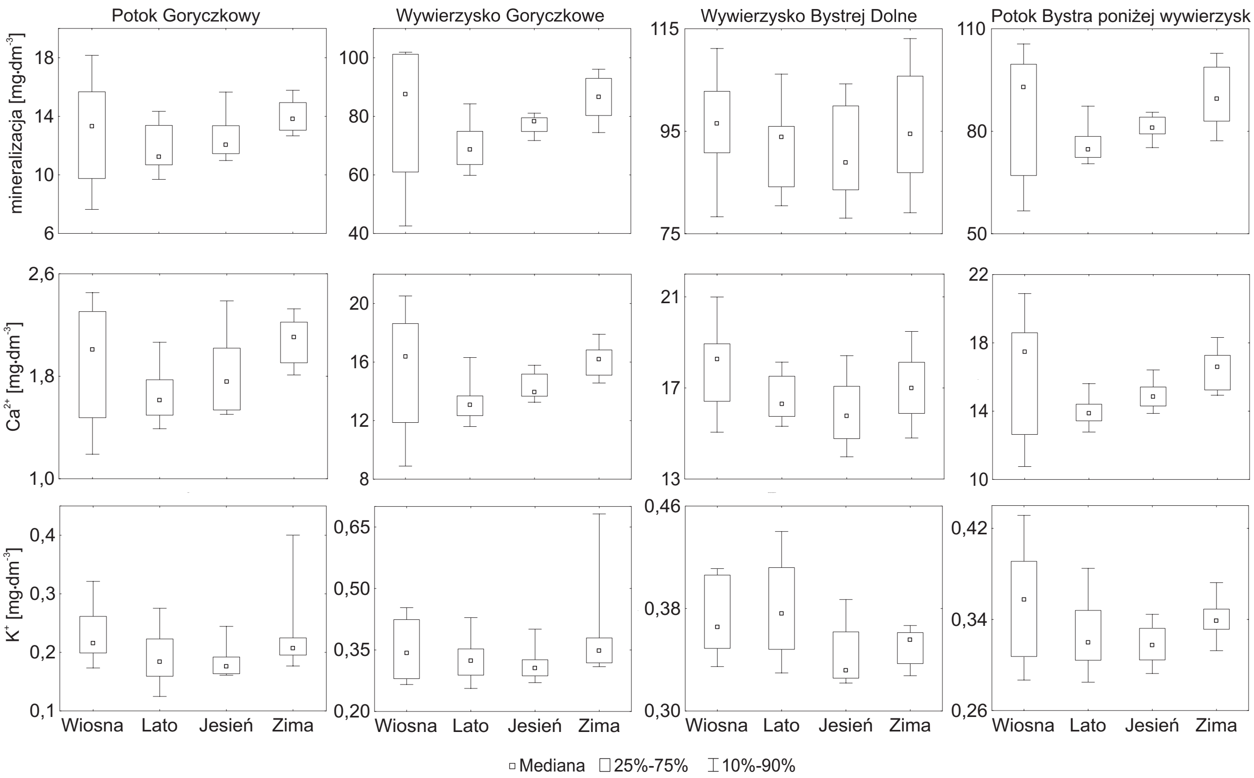

Fig. 4. Seasonal changes in mineralization, and in the concentration of Ca^{2+} and K^{+} in stream water

Source: Own study based on data

the crystalline and crystalline-sedimentary part of the Bystra stream catchment, the greater variability of the chemical composition of waters in the spring was noticeably higher than in the other seasons. In the lower Bystra karst spring, such a phenomenon was not observed. The variability of the chemical composition of water in the lower Bystra karst spring was clearly smaller than in the Goryczkowe karst spring, which is confirmed by lower coefficients of variation, generally not exceeding 15% (see: Table 3). Perhaps during very high flows, surplus water from Goryczkowy stream entered Goryczkowe karst spring – the surplus water that had not been absorbed in the ponor zone above the karst spring. The fact that the occurrence of such a phenomenon is very probable is evidenced by the existence of a dry bed above the Goryczkowe karst spring. This is also indicated by the high dilutions of the waters of Goryczkowe karst spring, especially during the spring thaw, for which the inflow of the low mineralized waters of Goryczkowy Potok (stream) would be responsible. Dilution of the waters in Goryczkowe karst spring is much larger than of the waters in lower Bystra karst spring (see: Figure 3). Goryczkowe karst spring is fed by the water from the Zielony Staw (pond) and the Myślenickie Turnie massif (Barczyk, 2008), whereas the lower Bystra karst spring is probably fed by the waters of the Giewont massif (Małecka, 1997) and from the valleys of the Małe Szerokie, Kondracka and Sucha Kondracka valleys (Gromadzka et al., 2015).

In all the studied waters, a clear decrease in NO_3^- concentration was observed during the summer and autumn months. Most probably, this was associated with increased NO_3^- uptake by plants during the growing season. In the waters of the streams draining the crystalline part of the Bystra stream catchment, there was clearly lower nitrate concentration than in the waters of the Bystra stream, draining the crystalline-sedimentary part. For instance, in the Goryczkowy stream, the average concentration of NO_3^- was

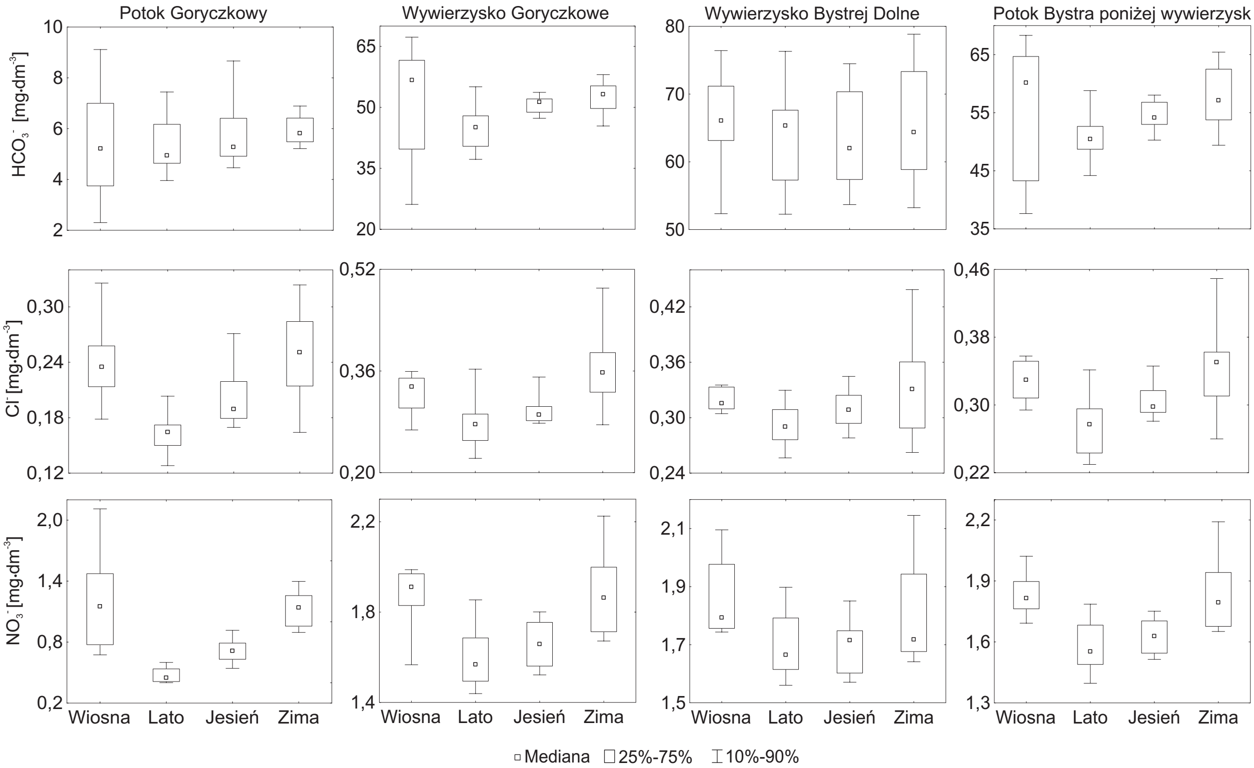

Fig. 5. Seasonal changes in mineralization, and in the concentration of HCO_3^-, Cl^- and NO_3^- in stream water

Source: Own study based on data

Table 3. Value of the coefficient of variation in the studied points

Feature		1	2	3	4	5	6	7	8
Sum total of ions	[%]	19.6	14.3	12.3	24.1	17.7	18.9	16.7	15.5
Ca^{2+}		17.3	14.5	12.5	23.7	17.1	20.9	18.6	13.9
Mg^{2+}		27.6	20.4	12.3	26.2	24.5	21.1	17.5	21.4
Na^+		9.9	7.4	8.4	8.0	11.8	12.8	13.0	15.1
K^+		32.2	52.6	24.7	18.6	36.4	34.2	33.1	42.0
HCO_3^-		20.1	13.5	13.6	29.7	16.7	28.3	24.4	22.6
SO_4^{2-}		26.7	32.4	14.2	10.4	38.3	13.5	11.4	13.2
Cl^-		39.8	16.0	18.8	26.0	19.6	27.7	20.5	39.8
NO_3^-		14.3	11.1	9.8	43.1	12.4	47.3	28.3	41.2

Source: Own study based on data

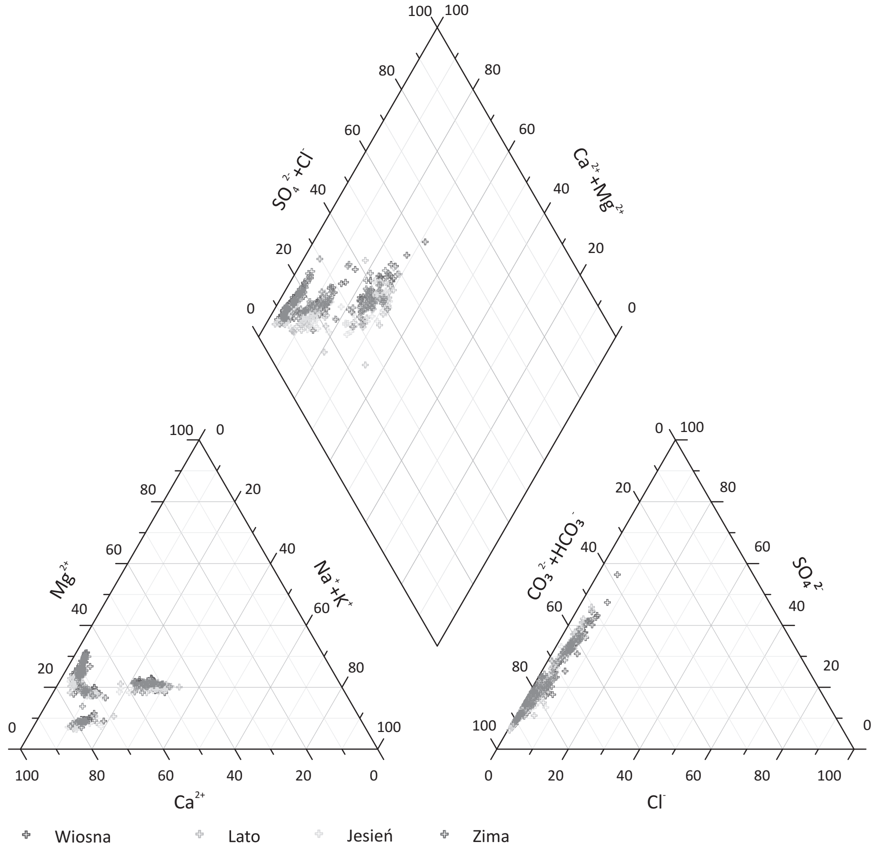

Fig. 6. The proportion of main ions according to season

Source: Own study based on data

0.9 mg · dm^{-3}, whereas in the Bystra Stream below the influx of water from the karst springs, it was twice as large: 1.8 mg · dm^{-3} (see: Table 3). The difference was most pronounced during summer and autumn. High variability of NO_3^- concentrations in the streams draining the crystalline part of the catchment in the spring is noticeable, which was not observed in the drainage of the crystalline-sedimentary catchments (see: Figure 5). The probable cause of such a high dynamics of NO_3^- concentration in the streams draining the crystalline part of the catchment was the leaching of NO_3^- from soils through the infiltrating melt-water, and their supply along with the waters of the interflow. NO_3^- concentrations in the water of karst springs were characterized by high stability throughout the year, as evidenced by the low coefficients of variation of NO_3^- (see: Table 3). This is reflected in minimal changes in NO_3^- concentration in the Bystra stream. The chemical composition of the water on the Bystra stream, draining the crystalline-sedimentary part of the catchment, was strictly dependent on the chemical composition of groundwater from Goryczkowe and lower Bystra karst springs. According to Wit and Ziemońska (1960), these karst springs are predominantly responsible for shaping the flow of Bystra stream.

CONCLUSIONS

The crystalline areas, due to the faster circulation of water, are characterized by a greater variability of flows throughout the year than the crystalline-sedimentary areas.

The crystalline part of the Bystra stream catchment is characterized by very low mineralization of waters, due to the circulation in sparingly soluble rocks. The waters of the crystalline-sedimentary part, the chemistry of which is shaped by the karst springs, are characterized by several times higher mineralization.

In all waters, in summer and autumn, during increased flows, a lower mineralization is observed, as well as lower electrical conductivity and lower ion concentration than in winter and spring, due to the dilution of groundwater with rainwater.

Spring is characterized by a greater diversification of the chemical composition of waters than other seasons. In early spring, the streams are mainly fed by groundwater with relatively high mineralization, and in late spring – by low mineralized water from melting snow.

In the stream waters draining the crystalline part of the Bystra stream catchment there was a demonstrably lower nitrate concentration than in the Bystra stream waters draining the crystalline-sedimentary part. During the summer and autumn months, all waters that had been tested exhibited a clear decrease in NO_3^- concentration, which was most probably associated with the increased NO_3^- uptake by plants during the growing season.

The chemical composition of water in the Bystra stream, draining the crystalline-sedimentary part of the catchment, was shaped by the chemical composition of underground waters from Goryczkowy and lower Bystra karst springs.

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REŻIM HYDROLOGICZNO-CHEMICZNY WÓD W ZLEWNIACH BYSTREJ I SUCHEJ WODY (TATRZAŃSKI PARK NARODOWY)

ABSTRAKT

Skład chemiczny wód powierzchniowych i podziemnych podlega ciągłym zmianom, których przyczyną są przede wszystkim czynniki meteorologiczne (np. wielkość i natężenie opadów atmosferycznych), czynniki hydrologiczne (np. stopień nawodnienia masywu górskiego i zmiany przepływu rzecznego) oraz geologiczno -litologiczne (rodzaj skał budujących podłoże). Celem badań było poznanie reżimu hydrologiczno-chemicznego wód powierzchniowych i podziemnych w zlewniach potoku Bystra i Suchej Wody.

Od grudnia 2013 r. do grudnia 2016 r. zebrano 77 serii pomiarowych w rytmie 2 razy w miesiącu (n = 611 prób wody) z 8 stanowisk, które reprezentowały zarówno wody powierzchniowe (cieki, staw) jak i podziemne (wywierzyska). Badany obszar cechuje się wyraźną dwudzielnością geologiczną. Południowa część to region krystaliczny, a północna część jest zbudowana ze skał osadowych. W terenie mierzono stany wody cieków, natężenia przepływu oraz cechy fizykochemiczne wód, takie jak przewodność elektryczna właściwa, pH oraz temperaturę wody. Równocześnie pobierano próbki wód do analiz laboratoryjnych, które obejmowały mineralizację ogólną oraz stężenia jonów Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^-, SO_4^{2-}, Cl^-, NH_4^+, PO_4^{3-}, NO_3^-, Li^+, Br^- i F^-.

Największy wpływ na skład chemiczny wód w zlewni potoku Bystra i Suchej Wody miała budowa geologiczna. Wody reprezentujące region krystaliczny cechowały się znacznie niższą mineralizacją ogólną, przewodnością elektryczną właściwą i stężeniem jonów niż wody w regionie krystaliczno-osadowym (krasowym). Średnia wartość mineralizacji ogólnej w regionie krystalicznym wynosiła 14,3 mg · dm^{-3} a w regionie krystaliczno-osadowym – 81,2 mg · dm^{-3}. Wody w regionie krystalicznym cechowały się wyraźnie niższym pH (średnia: 6,5 pH) niż wody w regionie krasowym (średnia: 7,7 pH).

Niskie wartości mineralizacji, przewodności elektrycznej właściwej oraz stężenia głównych jonów towarzyszyły podwyższonym przepływom w czasie lata i jesieni. We wszystkich badanych wodach zaznaczał się również wyraźny spadek wartości tych parametrów w okresie wiosennych roztopów. W zasilaniu potoków i źródeł (wywierzysk) w tym czasie znaczny udział miały słabo zmineralizowane wody roztopowe. Wiosną występowała też największa zmienność składu chemicznego badanych wód. Zmienność ta była wyraźnie mniejsza w wywierzysku Bystrej Dolnym niż w wywierzysku Goryczkowym, co najprawdopodobniej było związane z różnym tempem dopływu wód roztopowych do obu wywierzysk. We wszystkich badanych wodach najwyższe wartości mineralizacji ogólnej, przewodności elektrycznej właściwej oraz stężenia głównych jonów występowały w czasie zimowej niżówki, co wynikało z przewagi zasilania podziemnego w odpływie rzecznym. We wszystkich badanych wodach obserwowano wyraźny spadek stężenia NO_3^- w czasie miesięcy letnich i jesiennych. Najprawdopodobniej związane było to ze zwiększonym poborem NO_3^- przez rośliny w sezonie wegetacyjnym. W wodach potoków odwadniających krystaliczną część zlewni potoku Bystra występowało wyraźnie niższe stężenie azotanów niż w wodach potoku Bystra odwadniającego część krystaliczno-osadową. Skład chemiczny wód potoku Bystra, odwadniającego krystaliczno-osadową część zlewni, był ściśle uzależniony od składu chemicznego wód podziemnych z wywierzysk Goryczkowego i Bystrej Dolnego.

Słowa klucze: Tatry, hydrochemia, azotany, góry wysokie