SEASONAL CHANGEABILITY OF WATER FEATURES FROM WATERSHEDS WITH ARTIFICIAL NORWAY SPRUCE STANDS IN THE SILESIAN BESKID

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Abstract

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The investigation was conducted in the forest area of the Silesian Beskid, which belongs to Polish part of the West Carpathians. This part of the Carpathians is strongly influenced by air pollutants transported from Upper Silesian and Ostrava industrial regions therefore artificial spruce stands situated in this area have been under multifactor stress for many decades. There are three watersheds with dominating artificial spruce stands situated at different altitudes, differing in site and health conditions: Brenna (650–750 m a.s.l. moderate), Istebna (550–840 m a.s.l. good), Kamesznica (720–1214 m a.s.l. disastrous failures). In this paper results of seasonal changeability of pH, conductivity and concentrations of: SO_4^{2-}, Na^+, K^+, Ca^{2+}, Mg^{2+} in bulk precipitation, throughfall, stemflow and in outflow from watersheds for the period of April 2002–May 2003 are presented. The obtained results showed differences in water features among the watersheds as well as different dynamics of seasonal changeability in the analyzed water types. Effect of artificial spruce stands on the characteristics of the analyzed water is discussed.

Key words: mountain forest watersheds, bulk precipitation, throughfall, stemflow, stream water, Forest Promotion Complex "The Forests of Beskid Śląski", South Poland

Introduction

The Silesian Beskid belongs to Polish part of the West Carpathians and is located about one hundred kilometers from the Sudeten. Spruce contributes in 74.4% to the 40 500 ha area of forests in the Silesian Beskid. This part of the West Carpathians is strongly influenced

by air pollutants transported mainly from Upper Silesian and Ostrava industrial regions, therefore artificial spruce stands situated in this area have been under multifactor stress for many decades. However, the range of forest decline in the Silesian Beskid is much less than in the Sudeten, and concerns first of all the areas situated on the highest part of mountain ridge, where spruce stands are endangered also on damage from wind, drought, snow and hoarfrost (Staszewski et al., 1996, 1998, 1999; Bytnerowicz et al., 1999; Małek, 2002a, b; Niemtur, 2002; Niemtur et al., 2002, 2003). In spite of that in the Silesian Beskid Norway spruce stands famous for the highest quality not only in Poland ("Istebna" spruces) are also located. This diversifying of spruce stands quality in the Silesian Beskid is result of long history of forest management and characteristic for mountain areas wide scale of forest sites fertility.

Within the last decade a distinct decrease in air pollution level in Poland as well as in the Beskid Śląski is observed due to improvement of technology and emission control. However, existing levels of wet and dry deposition on the latter area may still adversely affect functions of forest ecosystems. Additionally, last changes of climatic conditions, particularly changes in annual rainfall and temperature distribution affect water balance and features of forest watersheds run off water.

Cumulating of rainfalls by short period leads not only to dangerous floods but also modifies circulation of nutrients by rinsing important elements from soil and plants. Course of this modification during last year was the most important game of presented investigation of changeability of water features in chosen watersheds. In this paper results of seasonal changeability of pH, conductivity and concentrations of: SO_4^{2-}, Na^+, K^+, Ca^{2+}, Mg^{2+} in bulk precipitation, throughfall, stemflow and outflow from three watersheds for the period of April 2002–May 2003 are presented.

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Material and methods

The investigation was conducted on three watersheds located in the Silesian Beskid in Forest Promotion Complex "The Forest of Beskid Śląski" with dominating artificial spruce stands situated at different altitudes, differing in site and health conditions: A/Istebna (550–840 m a.s.l.; good), B/Brenna (650–750 m a.s.l.; moderate), C/Kamesznica (720–1214 m a.s.l.; disastrous failures). Basic characteristics of watersheds are presented in Table 1.

Kamesznica watershed is located in upper part of torrent in the Barania Mts. (1214 m. a.s.l.) massif. The torrent is left inflow of the Sola river. Istebna watershed is located about 20 km on WWS direction from Kamesznica watershed and water from torrent inflows to the Olza river. Brenna watershed is located about 10 from Kamesznica on WWN and the water inflows in the Vistula river.

Water sampling was conducted in the period of April 2002–May 2003. Samples of bulk precipitation (marked as BP) directly reaching the catchment were collected each month with collectors installed in an open area at a distance of 150 m from the forest wall. In order to evaluate the quality of the throughfall (marked as TF) water was sampled each month from a sampling system installed under the canopy. The stemflow (marked as SF) was

collected each month from a sampling system (collar type collector) on three dominated trees according to the Kraft classification. Sampling of stream run-off on each watershed (marked as OF) was performed on the first day of each month. Water was analyzed with ion chromatography – Dionex for concentration of: Ca, Mg, K, and Na as well as conductivity and water pH were detected.

T a b l e 1. Basic characteristics of chosen watersheds in the Silesian Beskid.

Watershed Forest District Forest	Compart-ment	Area	Altitude	Sites*	Length of streams	Stand density	Area on 100 m of streams
		[ha]	[m]		m		ha/100m
A/Istebna Wisła Bukowiec	139–145	167.87	550–840	LMG BMG	5 770	0.7–1.0	2.9
B/Brenna Ustroń Stawy	118d, 122f	32.23	650–750	LMG	2 791	0.7–0.8	1.2
C/Kamesznica Węgierska Górka Sikorczane	176–191 196–199	436.55	720–1 214	BWG BMG LMG	13 200	0.3–0.8	3.3

BWG – high mountain coniferous forest, BMG – mountain mixed coniferous forest, LMG – mixed mountain forest

Results and discussion

In vegetation period the conductivity and pH of bulk precipitation were at similar level in all investigated watersheds. The lowest values of basic cations concentration were found in Kamesznica watershed. Brenna was characterized by the highest sulphate sulphur ($S\text{-}SO_4$) concentration what can be evidence of bigger exposition to air pollution from Upper Silesia and Ostrava industrial regions (Tables 1, 2). The lowest level of sulphate concentration in Istebna site reflects continuous decrease in concentration of this ion (1.44; 1.24; 1.00 for 2000, 2001 and 2002, respectively) (Małek, 2002a).

Tree crowns and especially surfaces of needles are places where dust pollution is deposited mechanically (Kabata-Pendias, Pendias, 1993; Kram et al., 1998) and partially removed by atmospheric precipitation. The effectiveness of the removal is different for individual ions (Poborski, Staszewski, 1996). It depends on many factors, i.e. inflow of ions, the presence of foliofags, concentration of elements in the foliage as well as the ion exchange rates.

Increase in concentration of basic cations after canopy passing (in throughfall) described by many authors (Stachurski, 1987; Zimka, Stachurski, 1996; Małek, 2002a) was strongly confirmed at three investigated watersheds (Table 2, Fig. 1). In spite of the presented above results of concentrations of sulphates in bulk precipitation, the increase in concentration of Ca within 2000, 2001 and 2002 in throughfall on the Istebna watershed (2.80; 4.02; 4.57, respectively) was found (Małek, 2002a).

T a b l e 2. Average concentrations of chosen elements, conductivity and pH in water during the vegetation period (May to Oct. 2002) in different kind of water from three watersheds in the Silesian Beskid.

Type of water	Watershed	Conductivity (µS/cm)	pH	Ca	Mg	K	Na	$S\text{-}SO_4$
				(mg/l)				
Bulk precipitation (BP)	Istebna	33	5.34	4.43	0.47	1.94	0.68	1.00
	Brenna	29	5.25	1.69	0.25	0.45	0.91	1.62
	Kamesznica	32	5.45	0.56	0.05	0.31	0.21	1.49
Throughfall (TF)	Istebna	37	4.36	4.57	0.62	2.96	0.59	2.33
	Brenna	47	4.68	2.90	0.68	2.09	1.34	2.77
	Kamesznica	61	4.47	2.48	0.36	3.48	0.64	3.13
Stemflow (SF)	Istebna	143	3.56	8.15	1.22	7.30	0.58	12.43
	Kamesznica	190	3.74	5.43	0.87	8.83	0.83	8.19
Outflow (OF)	Istebna	72	6.03	1.60	4.56	2.35	5.40	7.62
	Brenna	93	6.32	11.97	2.30	1.36	3.21	8.51
	Kamesznica	70	7.14	7.48	1.18	0.78	1.36	4.08

Enrichment of chemical composition of throughfall when compared to bulk deposition is a consequence of dry deposition of air pollutants to needle surface and leaching of ions from the needles. The rate of ions leaching is recommended as monitoring method to describe the level of needle injury. The high correlation between those factors was found (Arhoun et al., 2000).

T a b l e 3. The ratio of throughfall/bulk ions concentration at three sites.

Site	Ca	Mg	K	Na	$S\text{-}SO_4$
Istebna	1.03	1.32	1.53	0.87	2.33
Brenna	1.72	2.72	4.64	1.47	1.71
Kamesznica	4.43	7.20	11.23	3.05	2.10

Data presented in Table 3 show the increase in the ratio of throughfall/bulk nutritional elements concentration along with the worsening of spruce stands health status in the investigated watersheds (Tables 2, 3). It is no case for sulphate ion, however, the increase in its concentration in throughfall is known to be due to dry deposition and its leaching is negligible low (Bredemeier, 1988).

Conductivity values and concentration of sulphate sulphur ($S\text{-}SO_4$) in stemflow water were above three times higher and for Ca, Mg and K around two times higher than in throughfall water. Differences in water pH about 0,8 unit were also found (Table 2, Fig. 1).

The stream water pH was near to neutral. The lowest pH values were recorded during high water levels related to thaws. Electrolytic conductivity in running water was low (70–100 µS/cm). Calcium and magnesium cations and sulphate anions dominated in the outflow

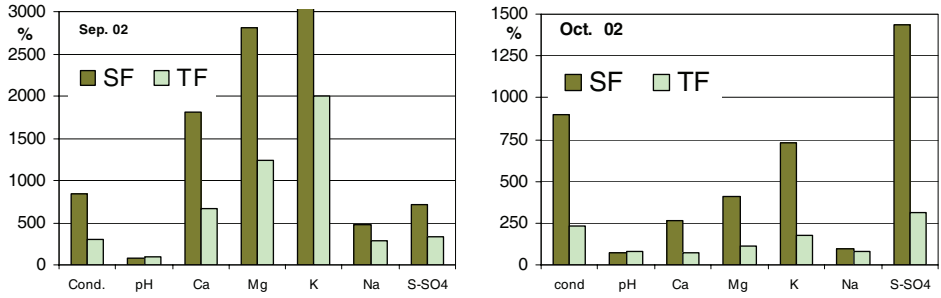

Fig. 1. Relations among the feature of different water type (SF stemflow, TF throughfall) at the end of vegetation season in Kamesznica (Sep. 2002) and Istebna (Oct. 2002) watersheds. Features of bulk precipitation water was used as 100%.

water. The concentrations of all analyzed elements (Table 2, Figs 2–4) were at the level noticed at the Babia Góra (Szczęsny, Zięba, 2001).

Cations are taken up on ion exchange sites in spring when concentrations in inflowing upland runoff are high, and subsequently released during summer months when concentrations in the input waters (rain) are lower (Urban et al., 1995). Retention efficiency is high when plants are actively growing and rapidly taking up nutrients, on the other hand reduced growth and even senescence lead to lowered retention (Verry, Timmons, 1982; Damman, 1986). Retention efficiencies in summer months are highest for those cations for which uptake into living plant tissue is important. Potassium which is taken up primarily into living tissue rather than onto ion exchange sites (Andrus, 1986) does not exhibit a net

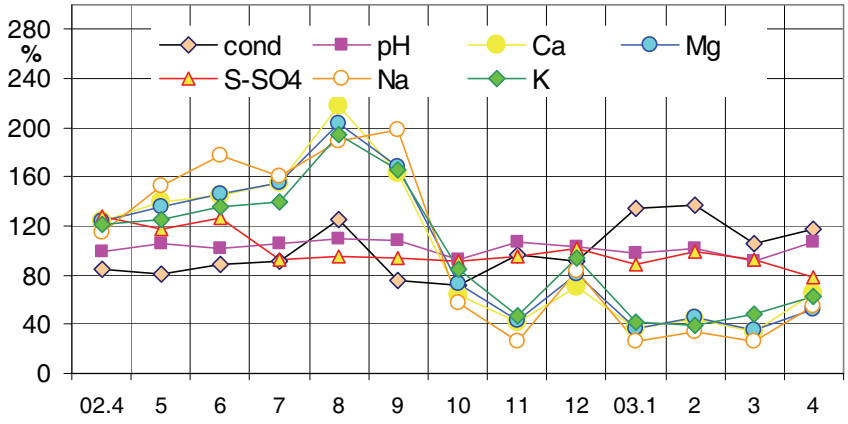

Fig. 2. Seasonal changeability of conductivity, pH and concentrations of elements [in % of deviation from average for all period] in outflow water from Istebna watershed.

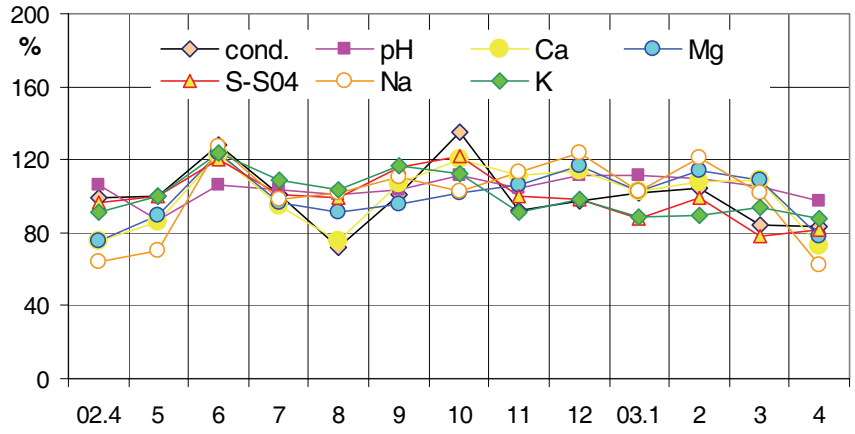

Fig. 3. Seasonal changeability of conductivity, pH and concentrations of elements [in % of deviation from average for all period] in outflow water from Brenna watershed.

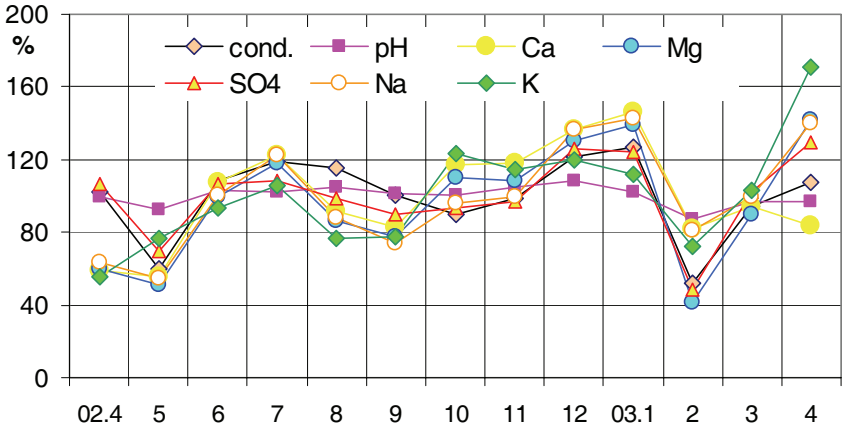

Fig. 4. Seasonal changeability of conductivity, pH and concentrations of elements [in % of deviation from average for all period] in outflow water from Kamesznica watershed.

export in summer months although retention efficiencies are lower than in spring and fall. A high correlation coefficient between sulphur-sulphate and potassium (0.83) in Brenna was found. Retention efficiencies are lowest in summer for Mg, which appears to undergo the least storage in biomass (Urban et al., 1995). A high correlation coefficient between sulphur-sulphate and magnesium (0.85) in Kamesznica was found.

Difference between vegetation period and wintertime in outflow waters in all analyzed watersheds was observed. In vegetation period, higher concentration of all analyzed elements and pH in Istebna, and higher concentration of Ca, Mg and Na in Brenna were found, whereas in Kamesznica it was a case for sulphur-sulphate and pH which can be the evidence of difference in bedrock and deeper water-bearing layers as well as episodic intensive storms during sampling period (Figs 2–4).

Outflow water was characterized by higher concentrations of Ca and Mg when compared to other water types, which testifies for leaching of those elements from watersheds and leads to deterioration of site conditions (Table 2).

The difference between bulk precipitation and outflow chemistry indicates the leaching of SO_4^{2-}, Na^+, Ca^{2+}, Mg^{2+}, and SO_4^{2-}, Na^+, K^+, Mg^2 in vegetation and wintertime period, respectively on all watersheds. This may cause unfavourable effect on the development and health of spruce stands (Małek, Gawęda, 2002).

Conclusions

1. In vegetation period the conductivity and pH of bulk precipitation were at similar level in three investigated watersheds. The lowest values of basic cations concentration were found in Kamesznica watershed. Brenna was characterized by the highest sulphate sulphur ($S\text{-}SO_4$) concentration what can be evidence of bigger exposition to air pollution from the Upper Silesia and Ostrava industrial regions. The lowest level of sulphate concentration in Istebna site reflects continuous decrease in concentration of this ion.
2. Increase in concentration of basic cations and sulphate ions in throughfall was stated at all investigated watersheds.
3. Increase in the ratio of throughfall/bulk nutritional elements concentration along with sharply visible the worsening of health status of spruce stands in the investigated watersheds was found.
4. The outflow level of: SO_4^{2-} Na, K, Ca and Mg which was observed on each watershed may cause unfavourable effect on the development and health of spruce stands.
5. Differences in anions and cations concentration in stream water from investigated watersheds are, the most likely, result of physiographic differences among three watersheds (episodic storm, altitudes, area, sites, stands, etc.).
6. Preliminary results of macro- and microelements dynamics investigation in three watersheds from Forest Promotion Complex "The Forests of Beskid Śląski" indicate also disadvantage conditions of predominant here spruce stands from meeting the needs of mineral nutrition point of view. This question requires further investigations of elements circulation in mountain forest watersheds in aspect of conversion of artificial spruce stands.

Translated by the authors

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Małek S., Niemtur S., Staszewski T.: **Sezónna premenlivosť charakteristík vôd rozvodí s umelými porastmi smreka obyčajného v Sliezskych Beskydách.**

Výskum sme zamerali na oblasť lesa Sliezskych Beskýd, ktoré patria do poľskej časti Západných Karpát. Túto časť Karpát veľmi ovplyvňujú škodliviny z priemyselných regiónov horného Sliezska a Ostravska, preto umelé smrekové porasty sú pod viacfaktorovým stresom trvajúcim niekoľko desaťročí. Nachádzajú sa tam tri rozvodia s dominujúcimi umelými smrekovými porastmi v rôznych nadmorských výškach, rozdielnych lokalitách a zdravotných podmienkach: Istebna (550–840 m n.m., dobré), Brenna (650–750 m n.m., stredne dobré) a Kamesznica (720–1214 m n.m., katastrofálne). V tomto príspevku prezentujeme výsledky sezónnej premenlivosti pH, vodivosti a koncentrácie SO_4^{2-}, Na^+, K^+, Ca^{2+}, Mg^{2+}, množstva zrážok, dažďov prekonávajúcich stromový zápoj, prietok a výtok z rozvodia v období od apríla 2002 do mája 2003. Získané výsledky poukazujú na rozdiely charakteristík vody medzi rozvodiami, ako aj na rôznu dynamiku sezónnej premenlivosti v analyzovaných vodných typoch. V príspevku diskutujeme o vplyve umelých smrekových porastov na charakteristiku analyzovanej vody.