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Variability of nephological conditions in 1971-2010 based on measurements made at Bydgoszcz-Airport weather station

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Abstract. This paper contains a description of nephological conditions in the Bydgoszcz area based on data sourced from the Bydgoszcz-Airport weather station for 1971–2010. In the analysed forty-year period from 1971 to 2010 the average annual total cloud cover in Bydgoszcz – measured on a scale of 0–8 – was 5.5; for the warm season (April – September) it was 5.1, and for the cold season (October – March) 5.8. This corresponds to, respectively, 69, 64 and 72% coverage of the sky by cloud. Cloud cover was largest from November to February (6.1–5.8) and smallest in August (4.7). In 1971–2010, the average mean cloud cover value (scale 0–8) decreased from 5.6 in 1971–1990 to 5.4 in the multi-annual period 1991–2010 (by 0.05 per 10 years).

Key words:
nephological conditions,
long-term variability,
Bydgoszcz,
Poland

Introduction

The Dictionary of Meteorology (2003) defines cloud cover as:

1. clouds covering the sky at a specific location,
2. the degree to which clouds cover the sky.

Clouds are one of the main factors affecting the radiation and thermal regime of the Earth. The occurrence of clouds is a result of the condensation of water vapour present in the atmosphere and is expressed as the total proportion of the sky that is covered by clouds of any level, as seen by the observer at a specific time. The degree of cloud cover is determined as a partial (scale 0–8) or percentage (0–100%) share of the whole sky.

Total cloud cover is not only an essential weather and climate factor, but also significantly affects the development of plants and the bioclimate in a locality or region. It is also a very important weather element that directly influences the character and safety of "aerial operations of aircraft", including at the Bydgoszcz-Szwederowo Airport.

Cloud formation and cloud cover development processes are a major issue for scientists in the context of global climate change. However, according to Żmudzka (2007), cloud cover, contrary to other weather elements such as temperature or precipitation, has been relatively poorly explored and is quite rarely a subject of study. The respective deficiency in Polish literature on climate studies is especially visible (Żmudzka 2014).

Regular weather measurements and observations in the Bydgoszcz area commenced in 1848, so there is already an extensive knowledge base on climate fluctuations, but it is often fragmentary and dispersed across multiple publications and based on data from different multi-annual periods and measuring stations. According to Łaszyca (2018), measurement data from the weather station set up

in 1924 within the premises of the airport located on a moraine plateau has been particularly underexploited. The station, located in open space, meets the condition for the results to be considered representative, which means it can refer both to the city of Bydgoszcz and to a wider area within a radius of several dozen kilometres.

Due to the low relief variation, the climate in the Bydgoszcz area is mainly affected by the free influx of air masses, with little impact of local factors (Araźny and Łaszyca 2020). According to data pertaining to the years 1981–1990, the weather in the Bydgoszcz area is mainly shaped by masses of humid polar-maritime air (75%), and to a considerably smaller extent by Arctic air masses from Greenland and Spitsbergen (16%), polar continental air from northern Russia and Baltic coast countries (7%) and tropical air masses (2%) from subtropical parts of the Atlantic and from the Mediterranean region (Bąk 2003).

According to Przybylak and Maszewski (2009), the high variability of weather and climatic conditions in the Bydgoszcz–Toruń region is due to its geographical location, as it is subject to impacts both from extensive areas of land to the east and from the Atlantic Ocean to the west. In the analysed area, just as in the whole of Europe, climate is affected by the neighbouring high atmospheric pressure centres – the Azores High all year round and the Siberian High in winter, as well as low atmospheric pressure centres – the Icelandic Low all year round and the South Asian Low in summer.

This paper aims to describe the characteristics of nephological (cloud formation) conditions in the Bydgoszcz area in the years 1971–2010, which have been developed for the months, the year, the summer and winter half-years, and the four seasons.

Material and methods

The work makes use of meteorological data from the period 1971–2010 sourced from the Bydgoszcz-Airport Weather Stations. In 1951–1982, under the auspices of the Institute of Meteorology and Water Management, a station operated at the airport (SZS code: 353170240; Ref: EPBY, according to the ICAO [International Civil Aviation Organisation]). In the period 1983–2010 the measurements of meteorological parameters were continued by the Military Aviation Meteorological Station (Ref: EPBW, according to the ICAO), providing meteorological services for military and civil aviation and standardised climate measurements and observations. In February 2007, at the airport in Bydgoszcz-Szwederowo, the station of the Institute of Meteorology and Water Management - National Research Institute was reactivated (SZS code: 253180220) and remained in operation until 31 December 2019 (Fig. 1).

Homogeneous data were obtained through a comparative analysis of results against those provided by the nearest representative weather station of the Institute of Meteorology and Water Management - National Research Institute Toruń-Wrzosy. All data have been carefully checked and ho¬mogenised using the Standard Normal Homogeneity Test (Alexandersson 1986) modified by Štěpánek (2008). The data series was determined to be homogeneous.

The data were used for analysis of the variability of monthly, periodic and annual mean values of weather elements in 1971–2010, and selected elements of descriptive statistics were calculated. Regression analysis was carried out and, based on the linear function, the direction and trends of changes of the analysed elements in time were determined. The study period was divided into two

Fig. 1. Location of the study area (marked with a star)

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Table 1. Cloud cover measured in octas and on the scale of 0-10

0-8	0-10
0 – clear sky	0 – clear sky
1 – 1/8 or less but more than 0/8	1 – 1/10 or less but more than 0/10
2 – 2/8	2-3 – 2/10-3/10
3 – 3/8	4 – 4/10
4 – 4/8 = 1/2	5 – 5/10 = 1/2
5 – 5/8	6 – 6/10
6 – 6/8	7-8 – 7/10-8/10
7 – 7/8	9 – 9/10 or more but less than 10/10
8 – overcast sky	10 – overcast sky

Source: own elaboration Author's reclassification after IMGW-PIB

twenty-year periods, that is, 1971–1990 and 1991–2010, and it was examined whether the extremity of respective meteorological parameters increased or decreased over time. The two indicators used in that case were standard deviation and value range.

The amount of total cloud cover was visually estimated by a weather observer. Until 31 December, 1988, cloud cover was determined on a decimal scale, i.e., from 0 to 10, and after 1 January, 1989 in octas, i.e., on a scale of 0 to 8. Therefore, for the needs of this work the total cloud cover was calculated in octas (0–8), (Table 1).

Results

The annual total cloud cover curve in Bydgoszcz was typical of the moderate climate of Poland (Fig. 2). A characteristic feature of this curve was greater cloud cover in the months of the winter half-year, especially in the winter months, and smaller cloud cover in the summer half-year. At the same time, higher cloud cover values are accompanied by lower variability in respective years, which results in lower standard deviation values.

The mean annual cloud cover in the Bydgoszcz area, measured on a scale of 0 to 8, amounted to 5.5 in the study period, 5.1 in the warm half-year (IV–IX), and 5.8 in the cold half-year (X–III), which corresponds to, respectively, 69, 64 and 72% sky cloud cover (Table 3). As regards respective months, the mean cloud cover was largest in November and December (6.1), and smallest in August (4.7), followed by May (5.0) and July (5.1). In terms of maximum and minimum mean total cloud cover by month, total cloud cover was largest in December 1993 (7.5), and smallest in July 1994 (2.5). As regards the analysed years, the largest total cloud cover was recorded in 1979 with the annual mean being 6.1, exceeding the multi-annual mean by 0.6. The smallest was in 1995, with the annual mean amounting to 4.8, that is, 0.7 less than the multi-annual mean.

In the study period, the mean total cloud cover was characterised by various changes over time, as described using a regression equation (Table 2). A definite majority were downward trends in mean total cloud cover over time for, for example, the whole year (Fig. 3A), the summer half-year, and most months. By contrast, upward trends in total cloud cover were identified for five periods in 1971–2010: these were February, November, December, the cold half-year and winter (Table 2).

Total cloud cover was highly variable between successive years. This is evidenced by standard deviation values and the extreme mean total cloud cover in the years 1971–2010 presented in Table 3. The highest standard deviation and the highest value range were observed in July, and then in May and June. In turn, the smallest variability in time was recorded for cloud cover in January, February

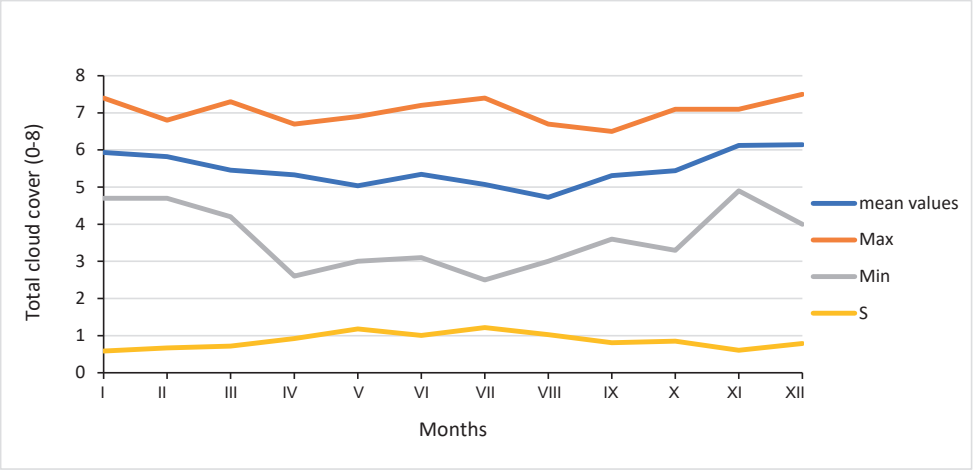

Fig. 2. Annual curves of multi-annual mean values, maximum (Max) and minimum (Min) mean monthly total cloud cover values and standard deviation (S) in the multi-annual period 1971-2010 in the area of Bydgoszcz

Table 2. Changes in total cloud cover (0-8) in the area of Bydgoszcz in the period from 1971 to 2010, including the coefficient of correlation and determination characterising the linear relationship

Month Period	Change over 10 years	Coefficient of determination R^2	Coefficient of correlation r
I	-0.010	0.0004	-0.0200
II	0.077	0.0181	0.1345
III	-0.047	0.0060	-0.0774
IV	-0.178	0.0514	-0.2267
V	-0.026	0.0006	-0.0244
VI	-0.161	0.0350	-0.1870
VII	-0.119	0.0130	-0.1140
VIII	-0.089	0.0102	-0.1010
IX	-0.166	0.0580	-0.2408
X	-0.067	0.0083	-0.0911
XI	0.068	0.0173	0.1315
XII	0.116	0.0297	0.1723
I-XII	**-0.050**	**0.0334**	**-0.1827**
IV-IX	-0.123	0.0373	-0.1931
X-III	0.018	0.0032	0.0566
III-V	-0.084	0.0256	-0.1600
VI-VIII	-0.123	0.0240	-0.1549
IX-XI	-0.055	0.0258	-0.1606
XII-II	0.052	0.0169	0.1300

Source: own elaboration Author's reclassification after IMGW-PIB
Key: critical value of the coefficient of correlation 0.3120 (α=0.05), 0.4026 (α=0.01)

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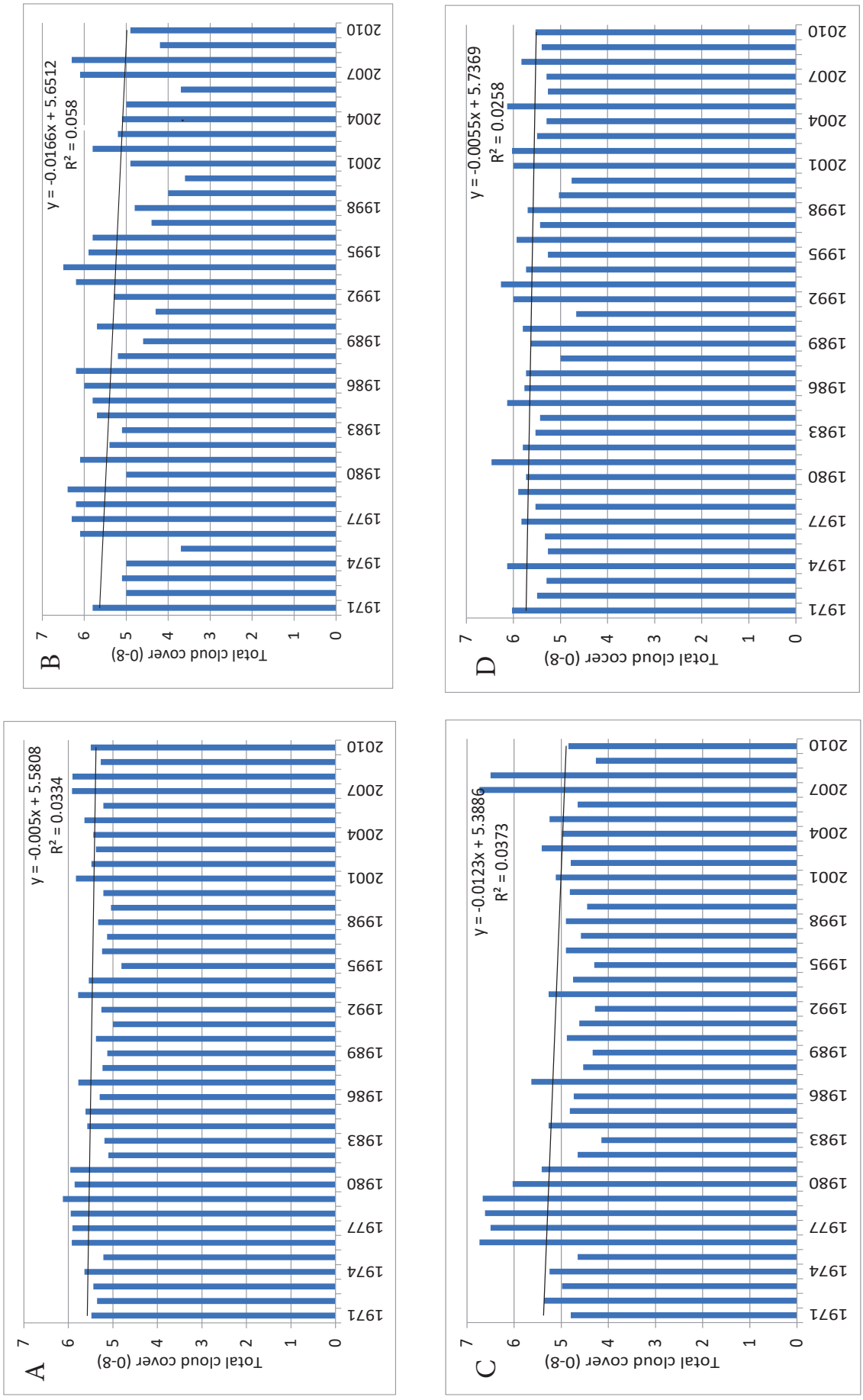

Fig.3. Mean total cloud cover values (on the scale of 0 to 8) and their trend in 1971-2010 in the area of Bydgoszcz: A - annual in total, B - in September, C - in the summer half-year (April-September), D - in autumn (September-October)

Table 3. Multi-annual (1971-2010) mean total cloud cover [0-8] in area of Bydgoszcz including temporal variability characteristics

Month Period	Mean	MAX Year	MIN Year	Range MAX-MIN	S
I	5.9	7.4 1994	4.7 1977, 2008	2.7	0.6
II	5.8	6.8 1973, 1993, 2004, 2009	4.7 1976, 2007	2.1	0.7
III	5.5	7.3 1985	4.2 1997	3.1	0.7
IV	5.3	6.7 2001	2.6 2009	4.1	0.9
V	5.0	6.9 1976, 1979, 2007	3.0 1990	3.9	1.2
VI	5.3	7.2 1976, 2007	3.1 1992	4.1	1.0
VII	5.1	7.4 1990	2.5 1994	4.9	1.2
VIII	4.7	6.7 1978	3.0 1997	3.7	1.0
IX	5.3	6.5 1994	3.6 2000	2.9	0.8
X	5.4	7.1 1974, 2005	3.3 1991	3.8	0.9
XI	6.1	7.1 1993, 2010	4.9 2007	2.2	0.6
XII	6.1	7.5 1993	4.0 1972	3.5	0.8
I-XII	**5.5**	**6.1** **1979**	**4.8** **1995**	**1.3**	**0.3**
IV-IX	5.1	6.7 1976, 2007	4.2 1983	2.5	0.7
X-III	5.8	6.7 1993/94	5.0 2007/08	1.7	0.4
III-V	5.3	6.4 1976, 2007	4.3 1990	2.1	0.6
VI-VIII	5.0	6.9 1976, 2007	3.1 1983	3.8	0.9
IX-XI	5.6	6.5 1981	4.7 1991	1.8	0.4
XII-II	6.0	7.1 1993/94	4.8 1976/77, 2007/08	2.3	0.5

Source: own elaboration
Key: MAX – the highest mean value in the multi-annual period, MIN – the lowest mean value in the multi-annual period, S – standard deviation

and November. Thus, the cloud cover was more variable in the summer half-year than in the winter half-year, and in summer in comparison to other seasons of the year. As regards extreme cloud cover values, more (31) were recorded in the twenty-year period 1991–2010 and fewer (21) in the previous period 1971–1990. This is a symptom of the recent growth in temporal variability of this parameter.

A comparison of determination and correlation coefficients shows that trends in total cloud cover over the years were the most discernible in: the month of September (Fig. 3B), the summer half-year (Fig. 3C), and autumn (Fig. 3D).

Comparing temporal variability of mean total cloud cover in 1991–2010 (the second 20-year period) with those in 1971–1990 (the first 20-year period), temporal variability was determined to be greater in four of the nineteen analysed time intervals (based on larger standard deviations and larger MIN–MAX value ranges) (Table 4). These were April, September, October and autumn. In five analysed time intervals (March, May, July, the warm

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Table 4. Comparison of indicators of temporal variability of total cloud cover in 1971–1990 and 1991–2010 in the Bydgoszcz area

Month	Standard deviation		Range (MAX–MIN)		Temporal
Period	1971–1990	1991–2010	1971–1990	1991–2010	variability
I	0.6	0.6	2.2	2.7	
II	0.7	0.7	2.1	2.1	
III	0.8	0.7	3.0	2.3	-
IV	0.7	1.1	2.4	4.1	+
V	1.3	1.0	3.9	3.7	-
VI	1.0	1.0	3.8	4.1	
VII	1.2	1.1	4.6	4.5	-
VIII	1.1	0.9	3.5	3.6	
IX	0.7	0.9	2.7	2.9	+
X	0.8	0.9	3.0	3.8	+
XI	0.6	0.6	1.9	2.2	
XII	0.8	0.8	3.1	3.3	
I–XII	**0.3**	**0.3**	**1.0**	**1.1**	
IV–IX	0.8	0.7	2.6	2.5	-
X–III	0.4	0.4	1.4	1.7	
III–V	0.6	0.6	2.1	1.9	
VI–VIII	1.0	0.8	3.8	3.2	-
IX–XI	0.3	0.4	1.5	1.6	+
XII–II	0.5	0.5	1.9	2.3	

Source: own elaboration
Key: + increased temporal variability, – decreased temporal variability

half-year and summer) the mean total cloud cover was less temporally variable in 1991–2010 than in the preceding 20-year period.

Discussion and conclusions

The Polish climatological literature is dominated by works that show the distribution of the average amount of cloud cover over the territory of Poland as well as sunny and cloudy days. These are mainly works that are part of studies on the climate of Poland (Schmuck 1959; Wiszniewski and Chełchowski 1975; Niedźwiedź 1981; Ustrnul 1994; Żmudzka 2003, 2004b; Lorenc 2005; Adamczyk and Ustrnul 2006; Żmudzka 2007; Filipiak and Miętus 2009; Wibig and Jakusik 2012; Kotarba 2016; Matuszko 2020). However, there are many fewer studies on cloud cover (Stenz 1952; Okołowicz 1962; Warakomski 1962; Chomicz and Kuczmarska 1971; Sypniewska and Szyga-Pluta 2018).

Nephological curves in Poland are also described in papers on climate (cloud cover) referring to respective regions (Schmuck 1948; Woś 1986) and in those reporting data from respective weather stations, e.g. Toruń (Wójcik and Uscka 1999).

Żmudzka (2007) claims that insufficient attention is paid to multi-annual changes in cloud cover, and believes that such studies are of descriptive significance as they refer to different aspects of variability in respective locations (stations), especially for those with long measurement series, e.g. Kraków (Matuszko 1998, 2003) and Łódź (Wibig 2003).

The annual total cloud cover exhibits relatively small spatial variability in the Greater Poland and Kuyavia regions (Woś 1996). According to measurements carried out by the Institute of Melioration and Grassland (IMUZ) in 1972–1995, the mean annual cloud cover in Bydgoszcz amounted to 6.5 on the 0–10 scale (5.5 on the 0–8 scale), and the sky is the cloudiest from November until January. Studies carried out by the present

authors for 1971–2010 showed that the mean cloud cover value on the 0–8 scale was 5.5. Cloud cover was largest from November to February (6.1–5.8) and smallest in August (4.7), May (5.0) and July (5.1). In the study period, the average mean cloud cover value (0–8 scale) decreased from 5.6 in 1971–1990 to 5.4 in 1991–2010 (by 0.05 per 10 years).

The results of the study can be used to develop a climatological guide for the Bydgoszcz-Szwederowo Airport and help in operations carried out for the needs of meteorological services for civil aviation such as planning and providing insurance for the flights of airplanes, helicopters and gliders, as well as military drills and operations and safe parachute jumping.

In addition, this paper contributes new knowledge and addresses the gaps in literature on climate studies regarding nephological conditions in the Bydgoszcz area.

Disclosure statement

No potential conflict of interest was reported by the authors.

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