Fog occurrence and chemistry in mountainous regions of Slovakia

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Abstract: Average number of days with fog in Slovakia over the observed period moved in an interval from 20 to 300 days. On the basis of average annual number of days, its annual course and orographic conditions, 4 main regions of the fog occurrence in Slovakia were distinguished and were also represented by fog limited prevalently to winter months. The region of mountain advective fogs is marked by the highest frequency of fogs and more or less by regular increase of days with fog on altitude (average gradient 20 days with fog per 100 m a.s.l.). For a more comprehensive knowledge of fog occurrence on the various territory of Slovakia, three stations were investigated in great detail: Sliač (valley), Telgárt (submontane slope location) and Chopok (Alpine ridge) where also analysis of the dependence of the fog occurrence on individual weather types was carried out. Cyclonal weather types are absolutely dominant in the fog formation in mountain regions. Towards the submontane regions up to hollows the proportion of cyclonal and anticyclonal weather types does not prevail (it reaches the maximum ratio 1:1). A field study was conducted on the mountain-top site in the Kremnické vrchy region (started in 1989, 890 m a.s.l.) and in a slope zone of Poľana mountain region (started in 1993, 850 m a.s.l.) respectively. Fog-cloud water has been collected by modified passive Grunow collector (sample area 1000 cm^2). The pH of fog/cloud ranged from 2.45 to 7.54 (Brestová) and from 2.54 to 7.30 (Poľana). The highest values of enrichment factors were obtained for NO_3^- (EF = 9-20 Brestova, 17-25 Polana). The time linear trend of pH values does not show any statistically significant long-term changes (Brestová). Linear trend of nitrate concentartion points out the nitrate increase in fog which is more pronounced in the locality of Brestova.

1. INTRODUCTION

Occult and wet deposition is very important as a source of input of chemical elements into forest ecosystems. As the wet pathways of acid deposition are connected with all kinds of precipitation - vertical (rain, snow etc.) and horizontal (fog, dew, rime etc.), it is necessary to obtain the data about physical and chemical parameters for each hydrometeor. The first results of the occurrence and chemical composition analyses of fog in Slovakia (Skvarenina 1990) made us consider fog as one of the potential cause of forest damage in mountainous regions in Slovakia.

2. METHODOLOGY

The occurrence and meteorological parameters of fogs in Slovakia were characterised by an analysis of data from 52 meteorological stations in the vertical range of altitudes from 200 to 2 000 m a.s.l. The average number of days with fog occurrence for individual months during a year over the period of 20 years (from 1971 to 1990) has been elaborated for individual meteorological stations. A detailed analysis of the vertical fog distribution and its duration expressed in hours as well as the relation of the fog occurrence according to individual weather situations has been made on a chosen altitudinal profile of the Low Tatras (Sliač, 313 m a.s.l. - Telgárt, 901 m a.s.l. - Chopok, 2008 m a.s.l.) .

The experimental sample plots for collecting the fog and the vertical precipitation were found in the following mountain regions: Poľana (slope location, 850 m a.s.l.) a Brestová (mountain valley, 890 m a.s.l.). For collecting of fog water a passive collector was used based on the principle of inertial impaction of fog droplets (Grunow 1955). Its collecting area is 1000 cm^2. The droplets of fog impact on the barrier of a collector and grow up to a larger diameter. Finally they flow down and are collected in a polyethylene bottle which is protected by aluminium folia against heating. The rain and snow water was collected in a polyethylene open collector with intercepting area of

1400 cm^2. Samples were gathered from collectors once a week and after every gathering the collectors were rinsed with deionized water.

Chemical analyses included measuring of the pH value and electric conductivity (EC) (Potentiometric method) and determination of soluble SO_4^{2-}, NO_3^-, NH_4^+, Cl^- (Ion chromatography), K^+, Na^+, Ca^{2+}, Mg^{2+} (ICP emission spectrometry, Atomic absorption spectrophotometry).

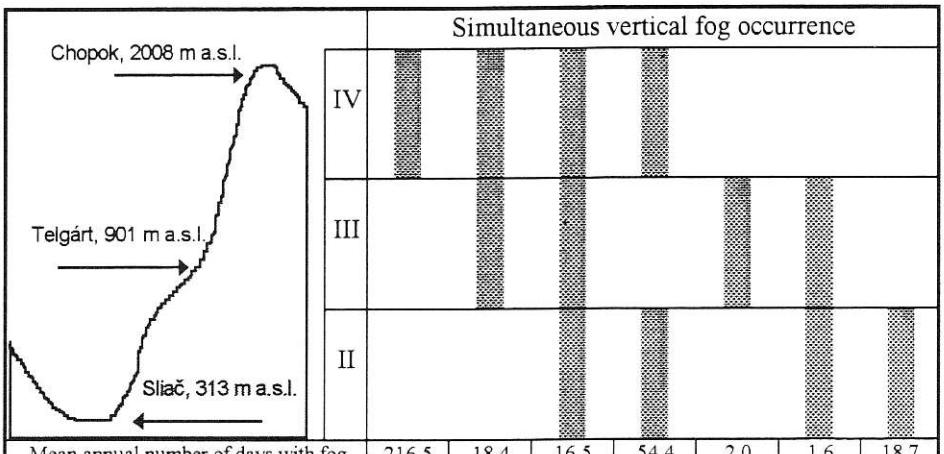
3. RESULTS AND DISCUSSION

3.1 Occurrence and characteristics of fogs in Slovakia

Average number of days with fog occurrence for the observed period moved in an interval from 20 to 310 days. On the basis of mean annual number of days with fog occurence, its annual course and orographic conditions 4 main regions of the fog occurrence in Slovakia (I, II, III, IV) were distinguished (Tab.1).

Table 1 Characteristic of individual regions of fog occurrence in Slovakia

Fog region	Mean annual number of days with fog occurrence	Geomorphological characteristic	Typical fog types	Ratio of cyclonic and anticyclonic weather types with fog occurrence (c:a)
I	20 - 45	Lowlands	advective radiation fogs advection fogs	1.3 : 1
II	40-100	Hollows, basins and valleys	radiation fogs, valleys fogs	1 : 1-2
III	20-50	Submontane and mountain slopes	inversion fogs, orographic fogs	4-3 : 1
IV	50-300	Top mountains	orographic fogs, frontal fogs, advection fogs	6-3 : 1



Mean annual number of days with fog	216.5	18.4	16.5	54.4	2.0	1.6	18.7
c : a	3.5 : 1	11.5 : 1	4.3 : 1	2.8 : 1	1 : 10	1 : 6.8	1 : 4.3

Figure 1 Characteristic of simultaneous vertical fog occurrence in Low Tatras region

Region I is characterised by a low fog occurrence with a very rare occurrence of fogs over the period from April to August.

Region II is characterised by the occurrence of the radiation fogs in anticyclonal weather types, mainly during the winter half of the year.

Region III is characterised by a combination of the occurrence of both the radiation and advective fogs. The isolated fog occurrence is rare in this region.

Region IV is characterised by different types of fogs whose dominant feature is dynamic character connected with warm or cold advection, transition of frontal systems (mountain-valley breezes), etc. This region is also characterised by the highest number of days with fog occurrence with the average vertical gradient of 20 days with fog occurrence per 100 m a.s.l.

Vertical fog occurrence was analysed on the basis of three meteorological stations characterizing individual regions of fog occurrence: Sliač-S (II), Telgárt-T (III), Chopok-Ch (2008 m a.s.l.). Average number of days with fog occurrence during the observation period, and the average duration of fogs expressed in hours per year was as follows: Sliač - 94 days, 477 hours; Telgárt - 34 days, 195 hours; Chopok - 309 days, 4864 hours. Results of the analysis of the structure of vertical fog occurrence are given in Fig. 1. The most frequent is the fog occurrence only on the Chopok station, the second most frequent occurrence has been found on the stations Chopok and Sliač. The analysis of the relation of fog occurrence according to individual weather types pointed out their significant differences (dominance of cyclonal situations at fog occurrence in mountainous regions, unlike the dominance of anticyclonal situations in the lower part of the vertical profile).

3.2 Fog/cloud chemistry in mountainous regions of Slovakia

The pH value of rain in natural conditions is thought to be ~ 5.6, which represents the acidity of pure water in equilibrium with the mean atmospheric concentration of CO_2 and other gases. However, the acidity of natural fog varies in different intervals than acidity of rain. The analyses showed that the pH of rain water, influenced by sulphur compounds, can be expected to be about 4.5 - 5.0. Therefore, the pH value of fog water below ~ 5.0 is assumed to be influenced by anthropogenic pollution (Li&Aneja 1992).

Basic Statistical characteristics of pH values (weighted mean, median, 25 and 75 percentiles, minimum and maximum values), are presented in Fig.2.

Comparison of the weighted means per year of fog samples in Brestová and Pol'ana points out slightly more acid values in the Pol'ana locality. The value of 75-percentiles suggests that more than 75 % of the samples analysed during the period of observation do not reach the value of 5.0, which is a limit detecting the influence of the anthropogenic pollution. The minimal pH-values found in individual years dropped mostly under the value of 3.0, being considered as extreme acid values. The analysis of the time course of the fog pH-value in Pol'ana and Brestová regions (Fig.3) has shown that low pH-values were found predominantly in winter period whereas the high pH-values, above 5.0, fall almost exclusively within the summer period. This fact can be due to the seasonal increase of emissions as a result of burning fossil fuels in winter period as well as to the decreased occurrence of the inorganic (soil and rock) aerosol (base cations) in the atmosphere during the occurrence of snow cover. The time linear trend does not show any statistically significant long-term changes. Unlike the found increased pH-values of precipitation (rain/snow) (Mitošinková 1997), the time linear trend does not show any statistically significant long-term changes.

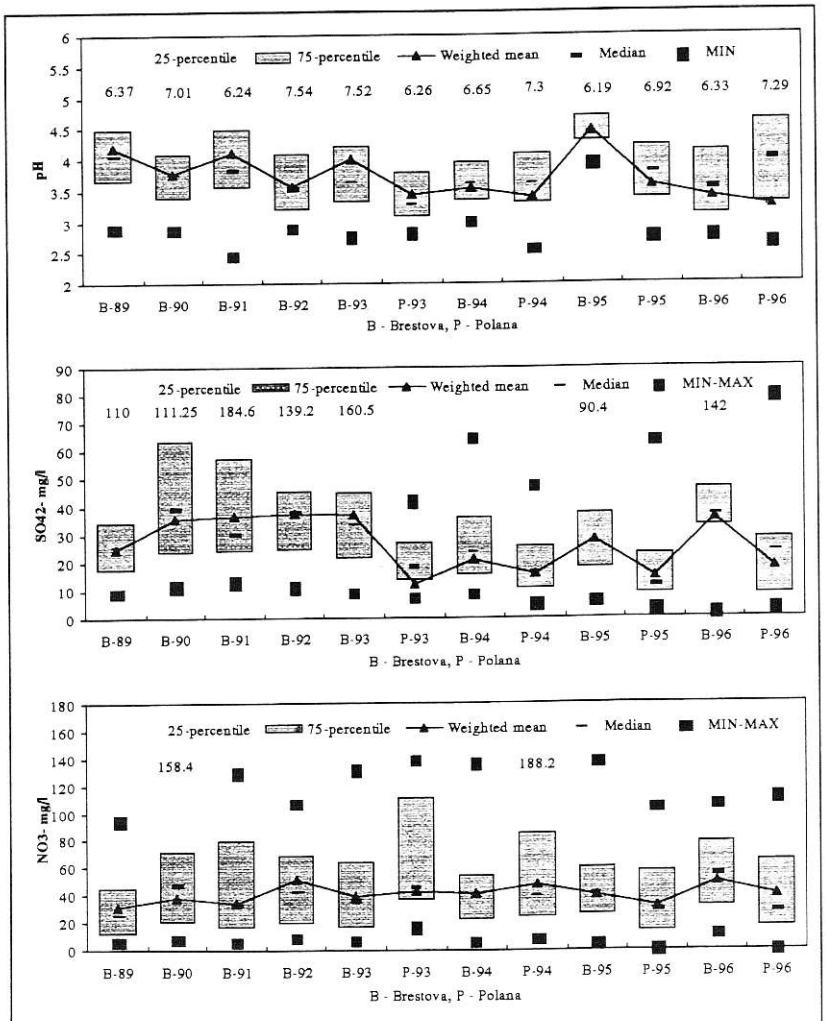


Figure 2 Statistical characteristics of pH values, sulphates and nitrates of fog/cloud water at Polana (1993-96) and Brestova (1989-96) sites

Sulphates. In Brestová, the annual weighted means of sulphates ranged from 20.7 to 37.5 $mg.l^{-1}$, in Pol'ana region from 11.6 to 18.0 being approximately twice lower values. In comparison with vertical precipitation, the sulphate concentrations in fog water are 2.3 - 4.6 times higher in the Pol'ana region and 3 - 5.6 times higher in Brestova region. Higher values in Brestova may be due to the local sources of sulphur emissions being approximately 15 km far from this region, which has been shown in the evaluation of trajectories of air circulation in relation to concentrations found in fog. (Škvarenina, Minďáš 1991).

Nitrates. Annual weighted means of the nitrate concentrations ranged from 32.6 to 48.2 $mg.l^{-1}$ in the Pol'ana region and from 34.7 to 51.24 $mg.l^{-1}$ in the Brestova region. Compared to vertical precipitation , they represent the highest factor of enrichment (Tab. 2). In Brestova, the proportion of sulphates and nitrates (annual weighted means) was 0.5-1:1, whereas in Pol'ana region it was lower ranging from 0.2-0.5:1. Linear trend of nitrate concentartion points out the nitrate

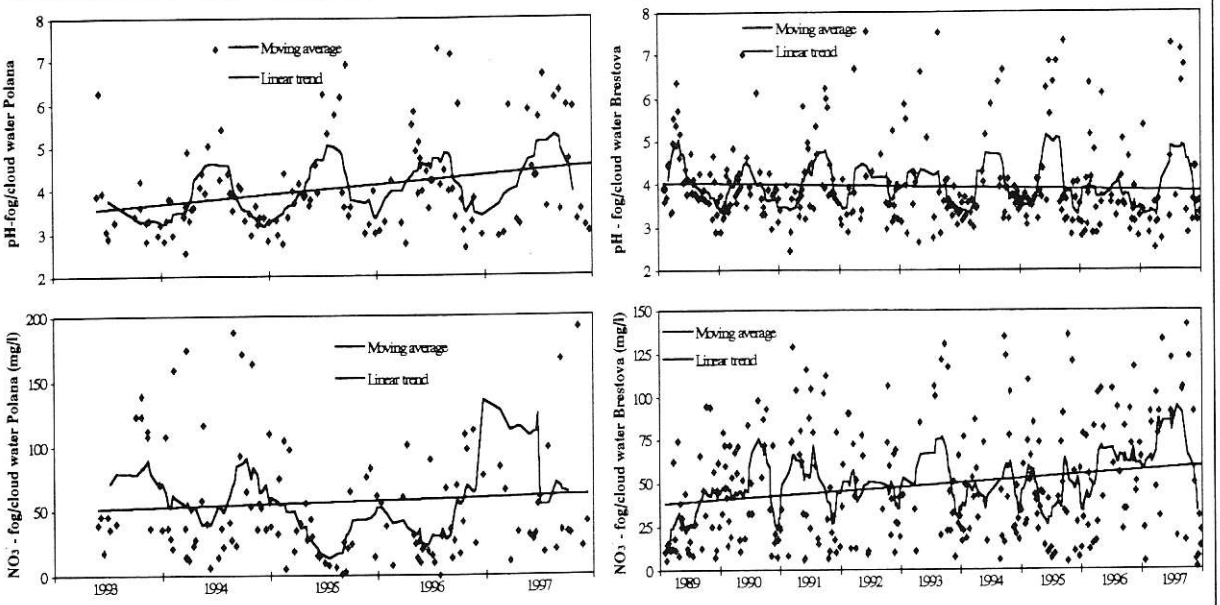


Figure 3 Time changes and linear trends of pH values and NO_3^- concentrations of fog/cloud water at Polana and Brestova sites

Table 2 Range of enrichment factors of fog/cloud water (compared to rain/snow water) for selected ions at Polana, Brestova and 2 sites in Bohemia

	SO_4^{2-}	NO_3^-	NH_4^+	K^+	Na^+	Ca^{2+}	Mg^{2+}
Brestova	3.0-5.6	8.8-20.2	3.8-8.5	1.1-3.3	3.9-11.0	5.3-11.9	3.7-6.8
Polana	**2.3-4.6**	**17.2-24.5**	**6.7-9.2**	**1.6-3.4**	**5.5-8.7**	**3.5-8.8**	**4.1-6.7**
Tesař et al. 1993	12	18	25	12	10	16	10
Moldan 1992	**8.2**	**6.8**	**9.2**	**2.0**	**4.0**	**5.7**	**3.9**

increase in fog which is more pronounced in the locality of Brestova. This fact is in keeping with the observed trends of nitrate occurrence in precipitation in western Europe (Matzner, Meiwes 1994).

Ammonium ion. Compared to nitrates, the concentartions of HN_4^+ were 2 - 3 times lower with the enrichment factor ranging from 3.8 to 8.5 (Brestová) or 6.7 - 9.2 (Poľana).

Base cations. From among the base cations (BC), calcium reaches the highest concentrations representing about 50 % of the total sum of BC and together with sodium, it reaches the highest enrichment factors in relation to vertical precipitation. (Tab. 2).

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