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Analysis of short – term heavy rains in eastern Slovakia in the period 2003 - 2018

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Abstract

Short-term heavy rains are one the most important rains from a meteorological, hydrological, and also technical point of view. When designing rainwater drainage systems or rainwater management systems, the intensity of short-term rains is used as a design parameter, because of short-term rains usually reach the highest intensity. This paper is focused on analysis of short-term heavy rains occurrence in the last 15 years in 3 rainfall stations in eastern Slovakia. The data used in analysis are automatically collected 10-minute precipitation totals at rainfall stations Poprad, Kamenica nad Cirochou and Košice.

Key words: short-term heavy rains, rainwater drainage, rainfall intensity, rainwater management

1 Introduction

Climate change has been a topic of interest to many researchers with multiple areas of expertise. One of the most important necessities of research into climate change is to analyze and detect historical changes in the climatic system [1]. Distribution of rainfall and its changes during the time is one of the most important aspects of climate change and it needs to

be investigated. Rainfall is one of the most important climatic variables because it affects important hydrological events such as floods and droughts. Rainfall and other hydrologic processes are known as stochastic processes. This is because they evolve in space and time in a way that is partly predictable or deterministic and partly random [2]. Rainfall and other hydrological processes are characterized for their variability in space and in time. There are many ways how to analyzed the variability, for example by examining trend, stationarity, homogeneity, periodicity or noise [3]. Long term rainfall data presents time series, which is a series of data points indexed in time order.

Analysis of rainfall data is very important in hydrology and also in engineering practice. Many authors in the world analyzed historical time series of rainfall in many countries in the world. In Asia, between Nepal and Tibet in the Himalayan region was showed that the annual precipitation amount is increasing in the period between 1943 and 1993 [4]. Similar results were presented also in other studies in many Canadian series [5] or in many places in South America, where authors analyze the number of rainy days per year and the daily rainfall amount [6]. In Europe, studies on Ireland series collected from 1940 to 1990 confirm the increasing of the total annual precipitation, in particular on the west coast [7]. Study from Ireland also shows how the intensity of rainfall is growing up and the return period of the extreme events is reducing. Results of this study is, that 30-year return period events are becoming 10-year events nowadays [8]. In Italy, it was proved that dry periods tend to be longer with increasing variability of the length of the dry spells and this is also associated with shorter duration of rain episodes with an evident effect on rainfall extremes [9]. In eastern Europe, there are some studies which documents the extremes of rainfall and their changes in time [10, 11].

In Slovakia, there are not many studies of rainfall time series in last years. Daily rainfall data were analyzed by Dub in 1950 and second, very complex analyze was done in 1973 by Šamaj and Valovič. Since these studies, not many authors have dealt with this issue. Statistical analysis of daily rainfall is very important for further use of data, for example for engineering practice. Rainfall, and its duration, intensity and frequency are very important in urban hydrology, for example in designing of sewerage or drainage system is cities.

Short-term precipitation, especially associated with storms, is a phenomenon in which the intensity of rain reaches a high value, while the duration of rain is usually short. Short-term precipitation is one of the main extremes in the weather [12]. Due to the high concentration of precipitation over time, short-term precipitation causes flash floods or landslides that cause large financial losses and causalities [13]. Events with high rainfall depths and durations of a few hours are most often associated with convective storms [14]. In Czech Republic, which is close neighbor of Slovak Republic it was reported, that the convective precipitation represents about 50% of the total precipitation in summer, and heavy rainfall events contribute significantly to precipitation in warm season [15]. Significant increasing trends in event rainfall rate and significant decreasing trends in event duration were found in Czech Republic [16]. This paper is focused on analysis of short -term heavy rains in Eastern Slovakia in the period from 2003 to 2018.

2 Study area and data

2.1 Study area

Analyzed rainfall stations are situated in the eastern part of Slovakia. These are the stations Kamenica, Košice and Poprad.
The Poprad city, where the first rainfall station is situated in the north of Slovakia, in altitude of 672 m close to the highest mountains of Slovakia, the High Tatras. Climate in this city is affected by topography of the terrain. Poprad is situated on the Poprad River in the Sub-Tatra Basin, and is a gateway to the High Tatras. Mountain ranges around the city include the Levoča Hills in the east, Kozie Chrbty in the south, and the Low Tatras in the southwest. The drainage divide between the Black Sea and Baltic Sea lies a bit to the west, near the village of Štrba [17].
The Košice is city situated in central part of eastern Slovakia near Hornád river in altitude of 208 m. It is situated on the river Hornád at the eastern reaches of the Slovak Ore Mountains, near the border with Hungary. Precipitation varies little throughout the year with abundance precipitation that falls during summer and only few during winter. The coldest month is January, with an average temperature of −2.6 °C, and the hottest month is July, with an average temperature of 19.3 °C. [18].
Kamenica nad Cirochou is situated in eastern Slovakia in altitude of 178 m and there are two rivers, Kamenica and Cirocha that merge approximately 1 km off the village. The location of each precipitation (rainfall) station is shown in Figure 1.

Figure 1: Location of the Poprad, Košice and Kamenica nad Cirochou precipitation stations in the eastern Slovakia

2.2 Input data

Input data used in this study consist of total rainfall per 10 minutes interval in each station from 2003 to 2018. Length of time series is 15 years. These data were automatically recorded and were obtained from the Slovak Hydrometeorological Institute (SHI), regional centre Košice. The value of total rainfall for the ten minutes interval was recorded at the end of each interval. There are no missing data in datasets, precipitation from all 10 minutes intervals are included.

3 Methods and methodology

In this paper, the occurrence of heavy rains in eastern Slovakia were analyzed. Heavy rains can be characterized in several ways. The easiest way is to characterization by the intensity of the rain (height of the water layer that hits the earth's surface in a certain time) [17]. This means that any rain that reaches a higher intensity than the set value is characterized as heavy rain. Boundary intensity values for the identification of heavy rains and downpours by Berg are given in the table.

Table 1: Characterization of heavy rains and downpours according to Berg on the basis of minimum rainfall intensities (H_s and I) for heavy rains and downpours **Chyba! Nenašiel sa žiaden zdroj odkazov.**

Duration (min)	5	10	15	20	25	30	45	60	120
Heavy rain									
H_s (mm)	2,5	3,8	5,0	6,0	7,0	8,0	10,25	12	18
***I* (mm/min)**	0,5	0,38	0,33	0,30	0,27	0,27	0,23	0,2	0,15
Downpour									
H_s (mm)	5,3	8,0	10,5	12,7	14,8	16,9	21,6	25,3	38,0
***I* (mm/min)**	1,06	0,8	0,7	0,64	0,59	0,56	0,48	0,42	0,32

It is clear from the table that a heavy rain for 10 minutes can be defined as any rain in which the rain intensity of 0.38 mm/min has been exceeded. Heavy rain is therefore characterized by a total rainfall of 3.8 mm per 10 minutes interval. Downpour is then characterized by a total rainfall of 8.0 mm per 10 minutes interval. In all three datasets (from Poprad, Košice and Kamenica stations for the period 2003 to 2018) all rainfalls with higher intensities then 0.38 mm/min and 0.80 mm/min were found and analyzed in this paper.

4 Results and discussion

For each station in every year, the number of occurrences of heavy rains (with more than 3.8 mm per 10 minutes) and downpours (with more than 8.0 mm per 10 minutes) were found. The number of heavy rains in observed period in the Kosice and in the Kamenica are more or less

the same (179 heavy rains in the Kamenica and 180 heavy rains in Kosice), but trend of heavy rains occurrences in these two stations are different. The fewest heavy rains occurred in Poprad station (134 heavy rains). The number of heavy rains in every year for every station is shown in Figure 2. There are also trend lines for each station. In Poprad and Kamenica station, there is positive trend in number of occurrences of heavy rains from 2003 to 2018. On the other hand, in the Kosice station, there is negative trend. The largest number of heavy rains in one year was 18 heavy rains in 2006 in Košice. In Poprad, the largest number of heavy rains was 17 in 2018 and the largest number of heavy rains in Kamenica was 15 in 2007. It is interesting that the largest number of heavy rains was observed in the Košice station in the years 2003 to 2011, while in the Poprad and Kamenica stations the number of heavy rains is constant or shows a slightly positive trend.

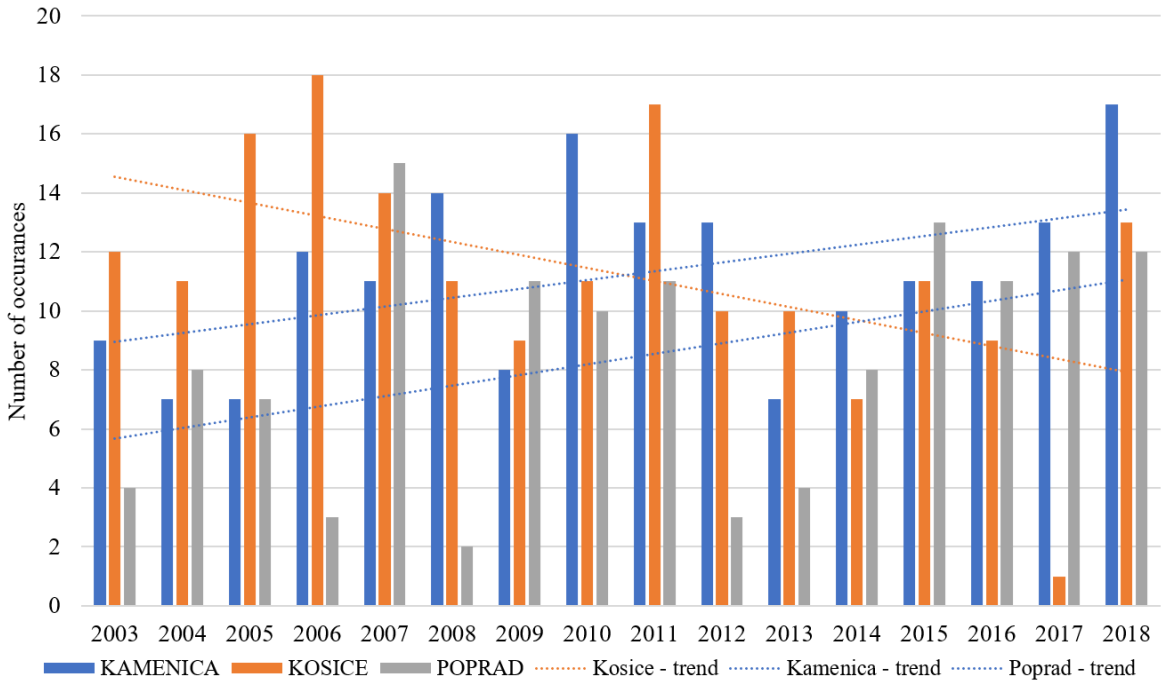

Figure 2: Number of occurrences of heavy rains for the period 2003 to 2018 in stations Kamenica, Kosice and Poprad

In the Figure 3 there is shown the number of occurrences of heavy rains in each month. It is clear from the graph in Figure 3 that heavy rains occur in all three stations in eastern Slovakia only in the summer season, very exceptionally in the spring and autumn season.

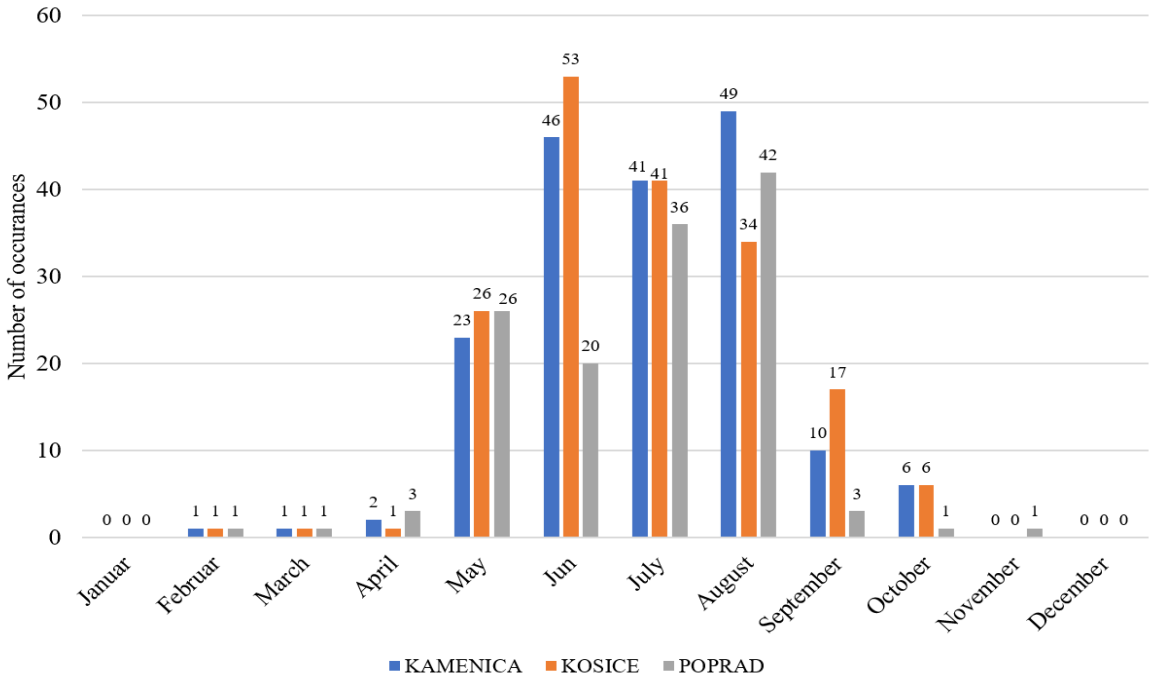

Figure 3: Number of occurrences of heavy rains in each month in stations Kamenica, Kosice and Poprad

In February, March and April, there were just few heavy rains in each station during the observed period. In May there is the start of the heavy rain season, which lasts until the end of august. This is due to the fact that heavy rains in the territory of eastern Slovakia occur mainly during storms, which occur during very warm weather. The largest number of heavy rains in Košice are in Jun, in Kamenica and Poprad station in August. In the Poprad station, the largest number of heavy rains are especially in second half of the summer, in July and August, it is because the climate of Poprad is affected by High Tatras mountains and climate here is affected, among other things by melting of snow in mountains. These two months, July and August, especially August, are also the warmest months of the year in Poprad.

The number of downpours with a total of rainfall more than 8.0 mm in 10 minutes is significantly lower than the occurrence of heavy rains with a total of more than 3.8 mm in 10 minutes. In total, downpours were observed at the Kamenica station 46 times during the observed period, at the Košice station 40 times and at the Poprad station 24 times. Significantly more downpours than in the Poprad station occurred in the Košice and Kamenica stations due to the higher temperatures that are reached in the summer months. The number of heavy rains in every year for every station is shown in Figure 4.

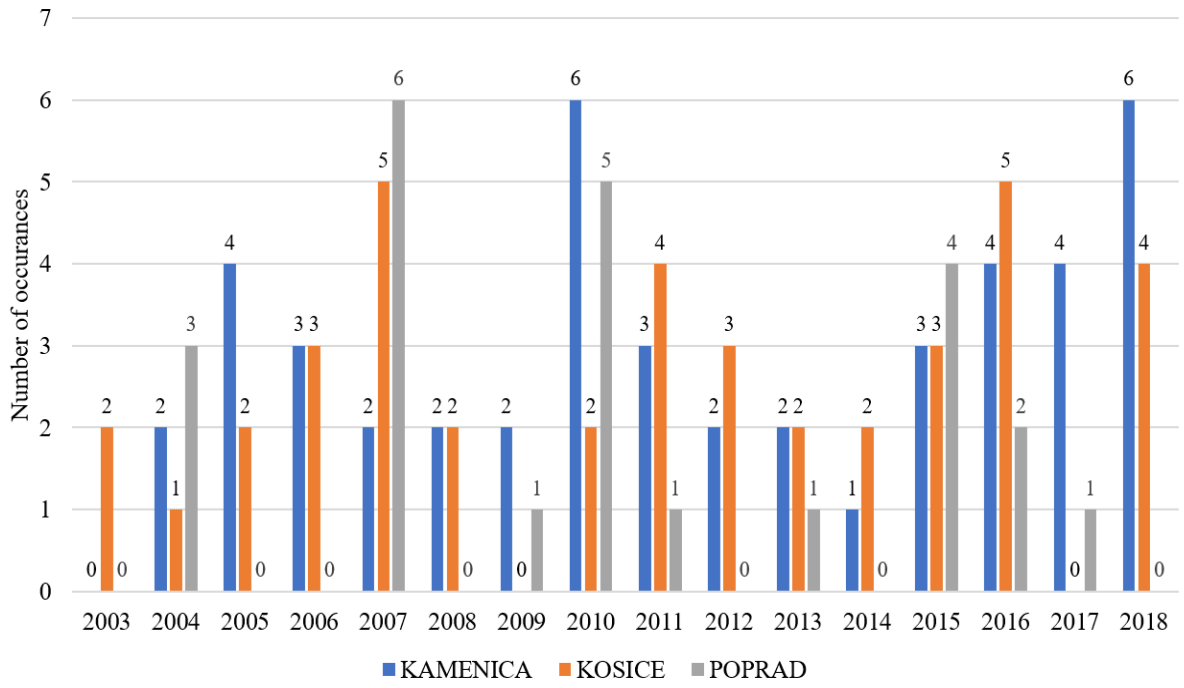

Figure 4: Number of occurrences of downpours for the period 2003 to 2018 in stations Kamenica, Kosice and Poprad

Downpours occur in all three stations exclusively in the summer months. The highest number of downpours (6) was observed at the Poprad station in 2007 and at the Kamenica station in 2010 and 2018. There were also many years during the observed period, when downpours did not occur at all throughout the year. Over the last 15 years (observed period) there has been no increase in the incidence of downpours in any of the observed stations.

5 Conclusion

Investigation of short-term heavy rainfall, which occurs in the Slovakia especially during summer storms, is very important, as these precipitations reach high intensities and cause considerable damage [20-23]. In this paper, the short-term precipitation was divided into heavy-rains and downpours, according to their intensities. Heavy rains and downpours were analyzed for the time period from 2003 to 2018 in three stations of eastern Slovakia. In Poprad and Kamenica station, there is positive trend in number of occurrences of heavy rains from 2003 to 2018. On the other hand, in the Kosice station, there is negative trend. The results showed, that heavy rains and downpours occur mainly in the summer months (from June to August), rarely in May and very exceptionally from Februar to April and in September and October. Heavy rains did not occur even once in the winter months during the observed period. The number of heavy rains during the year does not seem to have increased significantly. It seems that flash floods causing damage, which have occurred more frequently in eastern Slovakia in recent years, are mainly caused by changes in land use (urbanization, deforestation, monoculture agriculture), not an increase in the number of occurrences of

heavy rainfalls.

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