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CHARACTERISTICS OF PRECIPITATION CONDITIONS IN DOMANIÓW

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Summary. The paper presents characteristics of precipitations over the newly constructed water reservoir in Domaniów, situated on the Radomska Plain. The investigations covered the period from 2002 to the end of 2011. Mean annual precipitations total at that time was 517 mm; whereas the total for the warm half-year was on the level of 331 mm, and the cool half-year 186 mm.

The highest annual precipitations, 806 mm, were registered in Domaniów in 2010; it was an extremely wet year (156% of the average value for a decade). The highest mean monthly precipitation (2002–2011) was noted in July and reached 92 mm, whereas the lowest, 26 mm was registered in April. The highest monthly total precipitations 207 mm (226%) were noted in July 2011, in June 2010 – 108 mm, in May 2010 – 105 mm (196%) of mean ten-year value in this spot. On the other hand, the lowest monthly and annual total precipitations occurred in 2011; in November – 0 mm, in August – 13 mm (23%), in September – 5 mm (10%), in October – 12 mm (7%) and in December – 7 mm (24%). These were extremely dry months; the total annual rainfall was 433 mm (83%). This was a dry year.

Average annual total of days with precipitations with daily total > 0.1 mm was 113 days. The highest number of precipitation days was noted for daily precipitations ranging from 1.1 to 5.0 mm, whereas the daily rainfalls in the classes of 5.1–10 and 10.1–20.0 mm constituted the highest share in the total annual rainfall. Daily rainfalls over 20 mm were registered only in the summer months.

Analysis of the frequency and length of sequence of days without precipitations revealed that during the investigated period, there were 77 cases of 1st category drought (9–17 days), 20 cases of 2nd category drought (18–28 days) and 3 cases of 3rd category drought (> 28 days). All categories of droughts were observed most frequently in the second half of the year.

Key words: atmospheric precipitations, days with rainfall, droughts

INTRODUCTION

Atmospheric precipitation is a meteorological element characterized by a considerable changeability in time and space. Poland's location in the moderate and transient climatic zone favours the occurrence of extreme precipitation;

both high and low. Local diversification of the totals and frequency of precipitation are conditioned, besides circulation process, also by the land use and land features [Bokwa and Skowera 2008]. High precipitation and rainless periods causing droughts are the cause of ecological disturbances [Kożuchowski 1996].

The Domaniów water reservoir is situated in the zone of low average annual total precipitation (in comparison with the northern and southern regions of Poland) on the level of 525–550 mm over the 1966–1995 period [Koźmiński 2001] and between 500 and 550 mm for the 1971–2000 period [Lorenc 2005]. According to research conducted by Kanecka-Geszke and Smarzyńska [2007] Radomska Plain, where the reservoir is situated, is the area in which meteorological and agricultural droughts are most frequent. Extreme meteorological phenomena have been more frequently observed since the beginning of the nineties of the 20th century. The outcome of these phenomena are frequent deficit or excess of water influencing the vegetal cover, posing problems for water management, municipal services or hydroenergetics. The European Union legislation requires that the member states protect and manage water resources in a sustainable way (Framework Water Directive 2000/60/WE). The instrument supporting rational water management in the areas threatened with water deficiency or excess are artificial water reservoirs which make possible accumulation of water resources for various purposes [Jaguś and Rzętała 2000]. Knowledge of precipitation regime, i.e. the height, frequency and distribution of atmospheric precipitation, the duration and frequency of rainless periods, is crucial for proper approach to water management in retention reservoirs [Łabędzki 1997].

Construction of water reservoirs and proper water management in view of multifunctional rural development seems fully justified under meteorological and hydrological conditions of Poland. Occasional precipitation deficiency in relation to water requirements of various water users in the catchment, particularly agriculture, makes necessary water accumulation during the periods of its excess and use at the time of deficiency. Moreover, knowledge of precipitation conditions causes that the user of water reservoir – Management of Land Reclamation and Water Infrastructure in Warsaw, Radom Branch is capable of adjusting water intake to the needs of hydro-electric power station in the amount and in the periods of water needs in individual years [Łabędzki 1997].

Therefore, the paper determined time and quantitative total monthly and annual precipitations, the frequency of days with precipitation, as well as the occurrence and length of rainless periods, as the practical objective for the reservoir user.

MATERIAL AND METHODS

The precipitation station by retention reservoir in Domaniów is situated close to the earth dam (H = 149 m a.s.l., $\lambda = 20^{o}25'$E, $\varphi = 51^{o}25'$N). The station has been operating since 2001, i.e. for the whole period of the reservoir exploitation (Fig. 1).

Fig. 1. Location of Meteorological Station and precipitation station in relation to the investigated part of the Radomka River catchment

The Domaniów Water Reservoir is situated in the Radomka River valley, in the geographical macroregion of South Mazowsze Upland, the Radomska Plane mesoregion. Considering its administrative location, it belongs to the Przytyk, Wieniawa and Wolanów districts, in the Mazowieckie province. The reservoir was erected by damming up waters by means of frontal dam localised at km 64+800 of the Radomka River, about 4 kilometres from Przytyk village and stretches from the dam to Mniszek village. The reservoir was constructed in a flat accumulation valley, 600–1200 m wide [Kondracki 1998, Bonczar *et al*. 2005]. The main objectives of the investment are: equalizing water flows to eliminate deficit of water taken from the Radomka river for agricultural purposes, decreasing flood wave culmination, the use of dammed water for energy generation, the use of the reservoir for recreational purposes, equalizing the channel flow to ecological flow size.

The papers dealing with precipitation problems use basic statistical methods, i.e. total, mean, median, standard deviation and variation coefficient. The timing of multi annual and extreme precipitation is the most frequently presented for a decade, a month or a year, by means of computed pluviometric coefficient

which is ratio of total monthly precipitation to 1/12 total annual. Unlike other meteorological elements, precipitations are not continuous phenomenon, therefore for a fuller description of precipitation regime the number of days with various amount of precipitation is stated, as well as rainless and rainy days sequences and days of snow cover appearance, number of days with it and its thickness [Olechnowicz-Bobrowska 1971, Kossowska-Cezak *et al*. 2000]. Assessment of total monthly, seasonal and annual precipitation is conducted using a relative assessment of precipitations described by Kaczorowska [1962] and Przedpełska [1971]. Kossowska-Cezak [2000/2001] referring to the method suggested by Kaczorowska [1962] for precipitation assessment used the criterion of standard deviation from the average multi annual value.

Due to frequent rainfall deficiency in the area of Poland, many positions of climatological literature focus on drought assessment using standardised precipitation index (SPI) and standardised climatic water balance (CWB) [Przedpełska 1971, McKee *et al*. 1993, Łabędzki *et al*. 2002, Bąk *et al*. 2004, Kanecka-Geszke and Smarzyńska 2007].

The World Meteorological Organization recommends using long observational sequences (minimum 30 year-long) for climate characterization. In case of shorter sequences, the instruction allows the use of 10-year long periods as the norm [Janiszewski 1988].

The characteristics of atmospheric precipitations was prepared on the basis of annual rainfall totals measured on the Domaniów precipitation station during the period 2002–2011 and compared with the data from Meteorological Station in Kozienice [www.tutiempo.net/clima/KOZIENICE].

At the first stage decadal, monthly and seasonal totals were computed divided into the warm (May–October) and cool season of the year (November–April). Subsequently basic statistical values, i.e. mean, extreme values, standard deviation and coefficient of variation were computed for these periods [Kossowska-Cezak *et al*. 2000, Łomnicki 2003].

Monthly and annual total precipitations referring to average ten-year values were characterized using relative precipitations assessment method [Kaczorowska 1962].

Subsequently the number of days with ≥ 0.1 mm precipitation were characterized, monthly and seasonal number of days with precipitation was calculated divided into seven classes and total precipitations in individual classes [Olechnowicz-Bobrowska 1971]. Applied method enabled to learn the details of precipitation sequence.

Moreover, the duration of rainless sequences was analysed according to the criteria suggested by Schmuck [1969]. Three categories of atmospheric drought were identified: first category – the period of 9–17 days without rain, second category – 18–28 days without rain and third over 28 days. Single days with rainfall below 1mm or two subsequent days with total rainfall below 1 mm were classified to rainless days series. Single days with 1mm rainfall and higher were not classified to a given series.

RESULTS

The average annual total precipitation computed on the basis of ten years of investigations was 517 mm, total for the cool half-year (November–April) was 186mm and for the warm (May–October) 311 mm. The lowest annual precipitation occurred in 2011 and reached 433 mm, so according to Kaczorowska's classification [1962] it was a dry year with the most numerous extremely dry months (four cases) and very dry (two cases) – November was a rainless month (Tab. 1). The most rain abundant and wet was 2010, when the annual precipitation reached 806 mm in the summer, in the extremely wet half year 544 mm of rain was registered. Monthly rainfall in the investigated ten-year period was greatly diversified.

The months with average precipitation were the most frequent in the analysed multi annual period, however the most frequently observed dry were months (> 75% of the average precipitation) and wet months (> 125%). The weather conditions in October are worth noticing, since three cases of extremely low and three cases of extremely high precipitation were registered in this month in the 2002–2011 period (Tab. 1). More frequent occurrence of anomalous than average precipitation is characteristic for central Poland [Kossowska--Cezak *et al*. 2000]. October is characterized by the greatest variability of monthly total rainfalls, whereas September of decadal total rainfall (Tab. 2). Tendencies of precipitation variability coefficient development were confirmed by research of Węgrzyn and Galant [2000], Banaszkiewicz *et al*. [2004], Olechnowicz-Bobrowska *et al*. [2005]. The highest standard deviations of monthly rainfalls were in July – 59 mm and the lowest 12 mm in February. Decadal total precipitations revealed greater variability than monthly total and the highest standard deviations of these totals were from 28 mm in July to 7 mm in December (Tab. 2).

Management of water reservoir water resources requires more detailed understanding of the precipitation regime, e.g. decadal total precipitations or distribution of the number of precipitation days.

According to Lorenc [2005], average annual total of days with > 0.1 mm precipitation was 113 (Tab. 3), which was much lower than annual mean for this area, i.e. 160–170 days over the 1971–2000 multi annual period. The highest number, 135 days with precipitation > 0.1 mm was registered in 2007 and the lowest – 75 days in 2006.

Occurrence of days with very light precipitation (0.1–1.0) was little diversified – from 2 to 4 days in the subsequent months of the year. The average annual total precipitation in this class was only 29 mm. Very light precipitation is of no greater importance for retention reservoir water balance or for plant water economy. The most frequent in the scale of the year were days with light precipitation (1.1–5.0); on average 50 precipitation days which constituted almost half of the precipitation days per year, while total of precipitation in this class was 128 mm. Light precipitation occurred more frequently in the cool season of the year (28 days) and less frequently in the warm season (22 days). Total precipitations

Table 1. Sum of precipitation and humidity characteristisc of months and periods according to Kaczorowska [1962] in the period 2002–2011

Year	Months												Sum	Period	
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII		XI–IV	V–X
2002	31	33	24	9	52	88	62	50	37	70	33	19	507	149	358
2003	21	18	11	39	41	20	88	53	47	77	18	24	453	129	324
2004	31	53	47	66	38	34	60	36	17	33	47	11	472	254	218
2005	30	31	41	9	62	46	66	40	27	4	20	66	440	195	245
2006	34	26	29	23	37	29	8	172	15	17	51	19	460	183	278
2007	57	39	34	20	57	64	76	39	62	7	28	10	491	187	304
2008	45	8	51	42	54	19	54	43	63	30	28	41	476	213	263
2009	10	35	50	1	39	108	135	46	36	91	54	26	631	176	455
2010	51	35	29	25	105	59	161	73	140	7	77	44	806	261	544
2011	34	25	16	30	52	34	207	13	5	12	0	7	433	111	322
Average	34	30	33	26	54	50	92	56	45	35	35	27	517	186	331

Extremely dry
Very dry
Dry
Moderate
Wet
Very wet
Extremely wet

Table 2. Descriptive statistics of monthly and decade precipitation sums

Descriptive statistics	Months											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Monthly sums												
Average	34.3	30.2	33.1	26.3	53.6	49.9	91.7	56.4	44.7	34.8	35.4	26.5
Standard deviation	13.8	12.5	13.9	19.0	20.2	29.8	59.0	43.4	38.6	32.5	21.9	18.4
Coefficient of variation, %	0.40	0.41	0.42	0.72	0.38	0.60	0.64	0.77	0.86	0.93	0.62	0.69
Maximum	56.7	53.3	50.7	65.6	105.1	108.2	207.3	172.4	139.6	91.3	76.7	65.5
Minimum	10.1	7.6	10.7	0.9	37.2	19.3	7.5	13.2	4.5	4.3	0.0	6.6
Decade sums												
Average	11.4	10.1	11.0	8.4	17.8	16.6	30.5	18.7	14.9	11.2	11.8	8.8
Standard deviation	12.0	8.5	10.4	9.8	14.9	11.8	28.0	20.8	19.2	13.1	11.7	7.0
Coefficient of variation, %	1.0	0.8	0.9	1.2	0.8	0.7	0.9	1.1	1.3	1.2	1.0	0.8
Maximum	45	30	38.2	34.5	61	40.7	122.8	86.4	101.1	43.1	39.1	24.1
Minimum	0	0	0	0	0	1	0	0	0	0	0	0

in both periods in this class were respectively 71 and 50 mm. Lower frequency but higher annual and seasonal totals characterized moderate (5.1–10.0 mm) and moderately heavy (10.1–20.0 mm) precipitations. In comparison with very light and light precipitations, also their distribution in time changed. In both classes the number of days and total rainfall were higher in a warm season: 19 days and 176 mm of rainfall (Tab. 1, 3 and 4). Moderate precipitation occurred on average 2 days a month, whereas in March, April and December 1 day a month. Days with moderately heavy rainfall were noted more frequently in July (on average 2 days). The share of total precipitation of these classes constituted jointly over a half of annual total precipitations (Tab. 1). Days with heavy (20.1–30.0 mm) and very heavy > 30 mm precipitation were rarely noted. They occurred in a warm season, each year in July, sometimes in August, September and October. These total precipitations in both classes, on average 101 mm, have a considerable share in the total annual precipitation.

Occurrence of frequent sequences of rainless days poses a serious problem for water management in retention reservoirs. Water in such reservoirs is used for irrigation, and in case of the Domaniów reservoir also to secure continuous operation of the power plant. Therefore, the analysed multi annual period was characterized also regarding the frequency and length of rainless periods using criteria suggested by Schmuck [1969]. Occurrence of droughts in three categories was presented in Table 4. Drought categories were marked with three colours and their duration was presented by appropriate lengths of sections proportional to the duration of individual drought. During the analysed period the most frequent were category 1 droughts, lasting from 9 to 17 days, these were registered 77 times over ten years. Frequent occurrence of droughts is visible in 2005 when beside 1st category droughts (45 cases) also 2nd category droughts (18–28 days) were noted 20 times. More frequent occurrence of moderate drought (2nd category) is visible from July to December, except 2003 when two droughts of the 2nd category occurred in the period from February to April (Tab. 5). Also three cases of long-term, 3rd category droughts (more than 28 days) were registered. The first one in 2009 lasted four decades, from the beginning of April for the first decade of May. Only 1mm of rain fell during this period. Subsequent two long-term droughts occurred in 2011 during the period form the end of the first decade of September to December; the second drought lasted for 40 days. It was the driest month in the analysed period. A severe atmospheric, soil and hydrological drought lasted from August till December in the area of Poland [Bulletin of PSHM 2011]. Results obtained in the presented paper indicate that the area where the Domaniów water reservoir is situated is susceptible to meteorological and agricultural drought and are convergent with the results of Bąk and Łabędzki [2004], Kanecka-Geszke and Smarzyńska [2007] and Łabędzki and Leśny [2008].

Annual course and total annual precipitation for the investigated period are similar to the values for the 2002–2011 period obtained from the Kozienice station, situated about 20 km north east of Domaniów (Fig. 1). On the Radomska Plain, where Domaniów is situated, average annual total precipitation and the number of

Table 3. Mean number of days with precipitation according to Olechnowicz-Bobrowska [1971] in the period 2002–2011

Interval	Month												Sum	Period	
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII		XI–IV	V–X
> 0.1	12	10	9	7	11	10	12	8	8	9	10	7	113	55	58
0.1–1.0	4	3	2	2	3	2	2	2	2	2	3	2	29	16	13
1.1–5.0	5	6	5	3	4	4	4	3	3	4	5	4	50	28	22
5.1–10.0	2	1	1	1	2	2	2	2	2	2	2	1	20	8	12
10.1–20.0	1	0	1	1	1	1	2	1	1	1	0	0	10	3	7
20.1–30.0	0	0	0	0	1	1	1	0	0	0	0	0	3	0	3
> 30.0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1

Table 4. Mean total precipitation in classes in the period 2002–2011

Interval	Month												Sum	Period	
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII		XI–IV	V–X
> 0.1	34	31	32	27	54	50	91	56	45	35	35	27	517	186	331
0.1–1.0	2	2	1	1	2	3	1	1	1	1	2	1	18	9	9
1.1–5.0	11	15	12	9	11	9	9	9	9	10	13	11	128	71	57
5.1–10.0	8	10	9	6	15	16	15	14	13	13	11	10	140	54	86
10.1–20.0	10	4	10	6	11	19	26	18	8	8	5	5	130	40	90
20.1–30.0	3	0	0	5	15	3	16	7	4	0	4	0	57	12	45
> 30.1	0	0	0	0	0	0	24	7	10	3	0	0	44	0	44

Table 5. The occurrence of atmospheric droughts according to Schmuck [1969]

Year	Months																																			
	I			II			III			IV			V			VI			VII			VIII			IX			X			XI			XII		
	Decad																																			
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
2002																																				
2003																																				
2004																																				
2005																																				
2006																																				
2007																																				
2008																																				
2009																																				
2010																																				
2011																																				

Category drought

- I from 9 to 17 days without precipitation
- II from 18 to 28 days without precipitation
- III > 28 days without precipitation

precipitation days during the periods longer than presented in this paper are between 500 and 550 mm, whereas the number of days with precipitation over 1.0 mm for the 1965–1995 period [Koźmiński 2001] was 140 days, for the 1971–2000 period 160–170 days [Lorenc 2005]. Computed average annual and seasonal total precipitations in Domaniów for the 2002–2011 period were 517 mm and fall within the mean range value for the area, whereas the number of precipitation days (113) is much lower (Tab. 2 and 3). Due to a short period of precipitation station operation in Domaniów, presented analyses are only initial ones. Lower monthly and annual total precipitation in Domaniów as compared with the average for the area and similarity to precipitation course at the adjoining stations may indicate that the period of investigations overlapped the occasional decline in total precipitation [Kożuchowski 1996, Cebulska *et al*. 2007].

CONCLUSION

Atmospheric precipitation, constituting the main source of water, outflow, evaporation and retention are the main hydro-meteorological processes. The height, intensity and distribution of atmospheric precipitation is diversified in time and space. Atmospheric precipitation in the moderate climate visibly fluctuates seasonally, which was confirmed by conducted research.

Average annual total precipitations noted during the investigated period in Domaniów was 517 mm, whereas an average number of precipitation days (> 0.1 mm) was 113 days and were lower than area average for longer, 30-year periods 1966–1995 and 1971–2000.

In the years 2002-2011 there were 33 cases of months with rainfall over 125% of the standard (wet, very and extremely wet) and 43 with rainfall below 75% (dry, very dry and extremely dry). Warm season of the year (May–September) was very dry or dry four times, whereas cool season (November–April) three times. Bigger diversification of precipitation conditions occurred during the period from June to December.

The highest number of these days 135, was observed in 2007 and the lowest 69 days in 2006. Very light rainfall (0.1–1.0) was observed the least frequently whereas light rainfall (1.1–5.0 mm) the most frequently. The number of precipitations in this class was slightly higher in the cool season of the year. The highest total precipitations occurred in classes from 5.1 to 20 mm. Heavy (20.1–30.0 mm) and very heavy (> 30 mm) rainfall occurred the least frequently and only in summer.

The first category droughts were the most frequently registered – 77 cases, moderate droughts of the 2nd category – 20 cases, mostly in the second half-year. The 3rd category drought was noted three times –one case in 2009 and two cases in 2011.

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CHARAKTERYSTYKA WARUNKÓW OPADOWYCH W DOMANIOWIE

Streszczenie. W pracy przedstawiono charakterystykę opadów nad nowo powstałym zbiornikiem wodnym w Domaniowie położonym na Równinie Radomskiej. Okres badań obejmował lata od 2002 do końca 2011 r. Średnia suma roczna opadów wynosiła w tym okresie 517 mm; natomiast suma półrocza ciepłego kształtowała się na poziomie 331 mm, a chłodnego186 mm.

Największe roczne sumy opadów zanotowano w Domaniowie w wysokości 866 mm w 2010 roku. Według kryterium Kaczorowskiej [1962] był to rok skrajnie wilgotny (156% średniej wartości dziesięcioletniej). Największa średnia miesięczna (2002–2011) suma opadów wystąpiła w lipcu i wynosiła 92 mm, natomiast najmniejsza w kwietniu; 26 mm. Największe sumy miesięczne opadów zanotowano w lipcu 2011; 207 mm (226%), w czerwcu 2010 – 108 mm (216%), w maju 2010 roku – 105 mm (196% średniej wartości dziesięcioletniej w tym miesiącu). Natomiast najmniejsze sumy miesięczne i roczne wystąpiły w 2011 roku; w listopadzie – 0 mm, w sierpniu – 13 mm (23%), we wrześniu – 5 mm (10%), w październiku – 12 mm (7%) i w grudniu – 7 mm (24%) i były to miesiące skrajnie suche, a suma roczna wynosiła 433 mm (83%); był to rok suchy.

Średnia roczna suma dni z opadem z sumą dobową > 0,1 mm wynosiła 112. Największą liczbę dni z opadem zanotowano dla opadów dobowych w przedziale 1,1–5,0 mm, natomiast największy udział w sumie rocznej stanowiły opady dobowe w klasach 5,1–10 i 10,1–20,0. Opady dobowe powyżej 20 mm notowano tylko w miesiącach letnich.

Analiza częstości i długości trwania ciągów dni bez opadów atmosferycznych wykazała, że w badanym okresie wystąpiło: 77 przypadków posuchy I kategorii (9–17 dni), 20 przypadków posuchy II kategorii (18–28 dni) i 3 przypadki posuchy III kategorii (> 28 dni). Posuchy wszystkich kategorii częściej obserwowano w drugiej połowie roku.

Słowa kluczowe: opady atmosferyczne, dni z opadem, posuchy