NATURAL AND ANTHROPOGENIC FACTORS OF CHANGES IN WATER CONDITIONS IN THE SOUTHERN PART OF THE KRAKÓW-CZĘSTOCHOWA UPLAND

Wojciech Maciejowski

Jagiellonian University, Institute of Geography and Spatial Management, Department of Physical Geography

Abstract: The paper summarises research on changes of water conditions in the karst area of the Kraków-Częstochowa Upland, in the last forty years (1968-2008). Causes and effects are briefly characterised. The main causes are: periodical deficit or surplus of precipitation, fluvial bank erosion and changes of river channels, mining activity, pollution delivered with precipitation, intensive agricultural fertilising, areal contamination by nitrates and phosphates and uncontrolled sewage management. The main effect are: lowering of the water table, changes of the water springs functioning and even complete decline of some of them, disappearance of small streams, shortening of hydrographical network, pollution of ground waters and surface waters.

Keywords: Kraków-Częstochowa Upland, water conditions, groundwaters, river systems, changes factors

1. Introduction

Water constitutes one of the most important parts of the Earth's geosystem. Firstly, being the environment of life and a consumption material it is indispensable to life (Dynowska 1993), secondly, as an active component of the natural environment's system (Milkow 1981), very quickly responding to changes in internal structure and external stimuli, it modifies other components of the system, lastly, thirdly, circulating among them it is in incessant movement (Chełmicki 2001).

Changes, which water conditions undergo, may be a result of natural processes modelling the environment, understood as its functioning (*natural transformations*), as well as an effect of processes artificially induced by man (*anthropogenic transformations*). In an age of global environmental change, those changes attract increasing attention, and research results prove that effective water resources shrink continuously, both worldwide (Kundzewicz 2000, Mannion 2001) as well as in Poland (Chełmicki 2001).

2. Aim and methods of study

The aim of the study is to depict the causes of changes in water conditions which have occurred in the Kraków-Częstochowa Upland over the past 40 years as well as their effects on the functioning of the environment.

The paper constitutes a summary of fifteen years of the author's research upon the issues of transformations in water conditions in the Rudawka catchment being part of the Rudawa drainage basin. The research comprised comparative methods, confronting the author's investigations and observations carried out in the periods of 1992-1994, 1996-1999, 2001-2003 and 2006-2007 (Maciejowski 1996, 2000, 2001a, 2001b, 2003), with the state recorded in numerous previous publications. The object of comparative analysis comprised the depth of the water table (measurements in hydrogeological testwells using a fox whistle), the discharge of springs (using a velocimeter and a hydrometric float) and the length of river network (Instruction... 1964, Dynowska, Dynowski 1980). Data obtained from the Voivodship Inspectorate for Environmental Protection allowed to control the state of quality of surface waters. A completion was made by a range of other new information coming from papers for which research areas were constituted by the nearby upland catchments, amongst others the Dłubnia, upper Przemsza, Sanka and Prądnik rivers (amongst others Różkowski 1996, Soja 1997, Tyc 1997, Partyka 2001, Chełmicki et al. 2001, Chełmicki ed. 2001, Siwek 2001). Thus the collected data represent the entire area of the southern part of the Kraków-Częstochowa Upland (*Figure 1*).

3. Study area

The southern part of the Kraków-Częstochowa Upland extends north-west of Kraków on an area of more than 1320 km^2 (*Figure 1*). It constitutes the highest part of the entire region, formed by an undulating plain, cut by deep valleys. Above the plain rise isolated mogotes, among which the highest reaches a height of 512 m asl. In the west the Upland falls with a steep and high (up to 100m) edge of a cuesta character. The

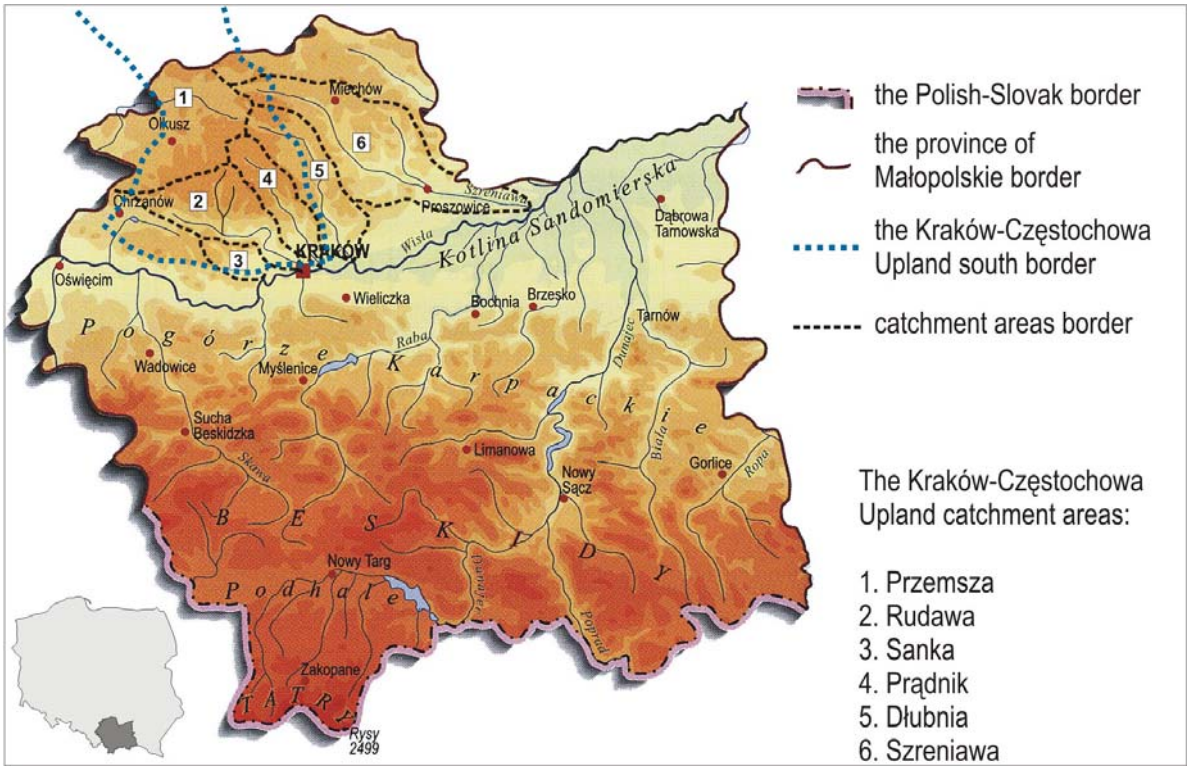

Figure 1. Map of the southern part of Kraków-Częstochowa Upland with catchment area borders (the base map of the province of Małopolskie is taken from the Atlas of Poland 2001)

bedrock is made up of strongly karstic carbonate rocks (mainly limestones of the Upper Jurassic), covered by a fairly thin layer of the Quaternary loess. The mean annual temperature is from 7,0-7,6°C on the plain to 7,8-8,2°C on valley floors, while the annual precipitation does not exceed the value of 840 mm. The surface waters network is characterized by the groundwater-snowmelt-rainfall supply, and only few by the snowmelt-rainfall supply. The prevalent part of the region is covered by a mosaic of arable land, meadows and pastures and built-up grounds, excluding the southern fringe, where larger complexes are formed by forests.

In the administrative division of Poland the whole area lies within the boundaries of the province of Małopolskie.

4. Transformations in water conditions in the southern part of the Kraków-Częstochowa Upland

All investigations conducted in the catchments of the southern part of the Kraków-Częstochowa Upland indicated transformations which have affected water conditions in the period of forty years 1968-2008. They include:

1. lowering of the water table in the western and north-western part of the discussed area in places reaching even 40 m (Hydrogeologic Map 1986, Sawicki and Gutry-Korycka 1993, Soja 1997), and its periodic oscillations (decrease, increase, and recently decrease again) from 0,5 to 1,5 m – (*Figure 2*) (Maciejowski 2000),
2. change of the natural direction of groundwater flow (Maciejowski 2000),
3. complete or periodic disappearance of small (<1 l/s) and middle-sized (1-10 l/s) springs; for example in the Rudawka catchment at least 13 springs dried out and 3 other are active periodically (Maciejowski 2000), whereas in the vicinity of Ojców 20 springs completely disappeared (*Figure 2*) (Partyka 2001),
4. considerable variability in time of the discharge of middle-sized (1-10 l/s) and large (>10 l/s) springs, amongst others for several springs a decrease in discharge even of 20-50% was recorded, then an increase by 20-25% (Maciejowski 2000),
5. disappearance of small streams and a shortening of hydrographical network (Sawicki and Gutry-Korycka 1993, Maciejowski 1996), amongst others in the Rudawka catchment by 2,3 km i.e. 7% (Maciejowski 2000),
6. fluctuations of stream discharges (*Figure 3*) (Soja 1997, Maciejowski 2001),
7. periodical disappearance of flood-type freshets (Maciejowski 2001),
8. water transfers between catchments (Sawicki and Gutry-Korycka 1993),

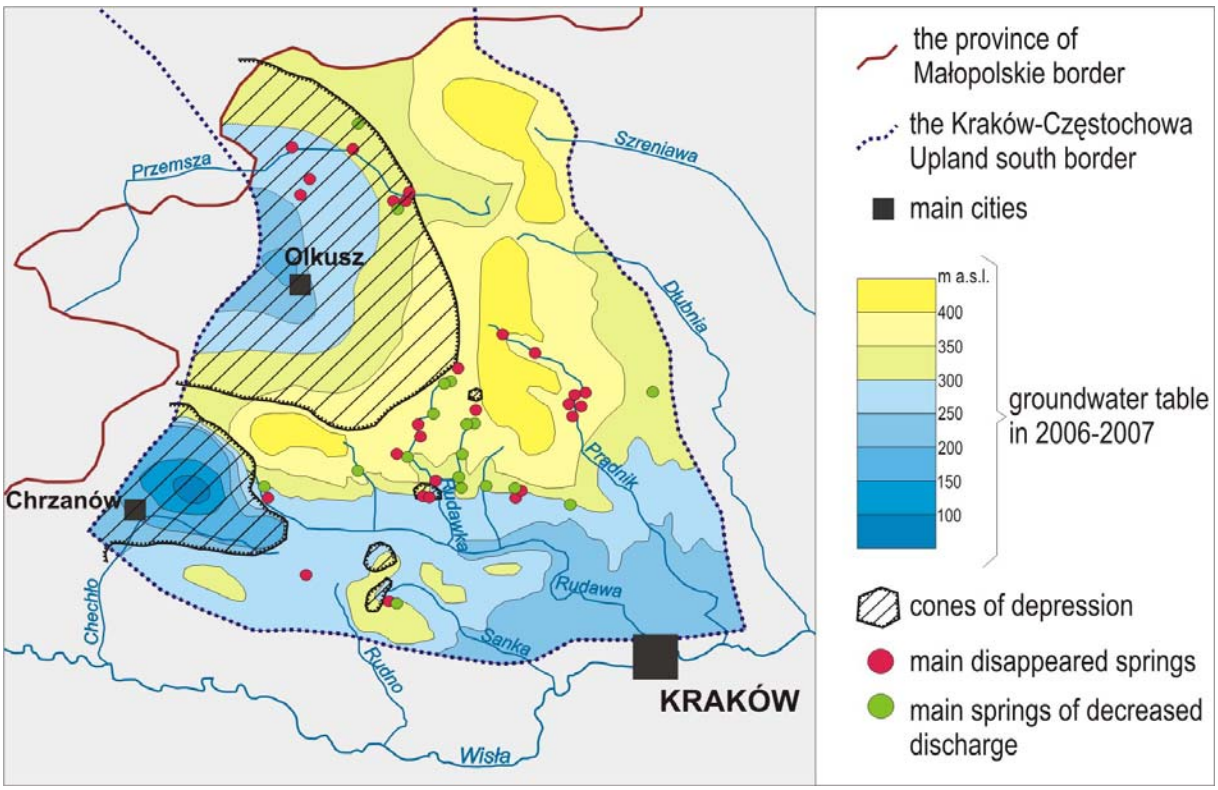

Figure 2. Groundwater table in 2006-2007 and its lowering in the western and north-west part as cones of depression (source: author's compilation based on Hydrogeologic Map 1986, Sawicki and Gutry-Korycka 1993, Soja 1997, Maciejowski 2000, Partyka 2001 and author's research 2006-2007)

Figure 3. Upper part of the Szklarka river in 1993 (left) and 2001 (right)

9. contamination of groundwater, mainly by nitrates and phosphates (*Figure 4*) (Różkowski 1996),
10. contamination of surface waters by heavy metals, mainly zinc and cadmium (Różkowski 1996) and oil-derived substances,
11. changes of the quality of groundwater and surface waters (Chełmicki ed. 2001, Partyka 2001) over the whole investigated area, expressed by an increased content of nitrates and an increase in water mineralization (by 25-45% on average),
12. littering of river channels and spring alcoves (Różkowski 1996, Maciejowski 1996).

All the transformations in water conditions listed above were observed in the majority of catchments of the southern edge of the Kraków-Częstochowa Upland, though some of them are only characteristic of single, small catchments.

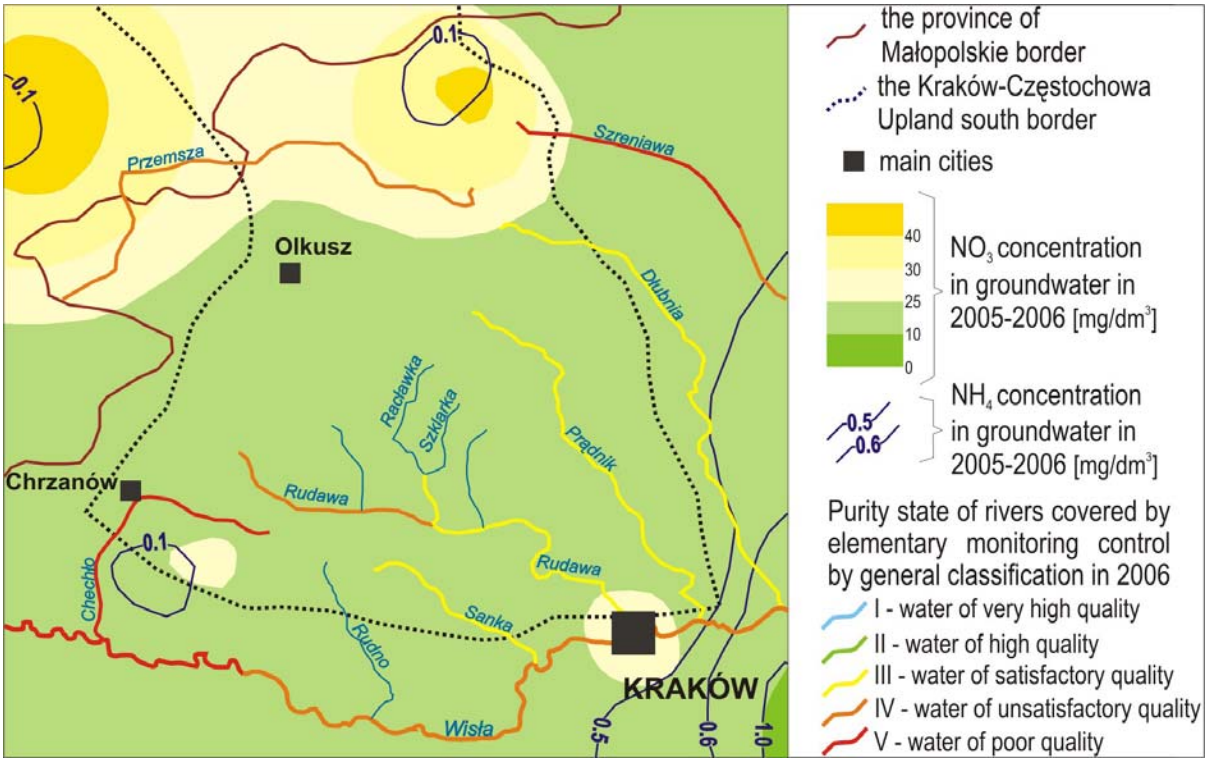

Figure 4. Nitrates concentration in groundwater and purity state of rivers (source: author's compilation based on Chełmicki ed. 2001, Synowiec et al. 2007, The State of... 2007 and author's research 2006-2007)

5. Causes and results of transformations in water conditions and their influence on the functioning of other elements of the environment

The lowering of the water table in the Kraków-Częstochowa Upland is connected with the large area of influence of a cone of depression formed by the pumping out of groundwater in zinc and lead mines of the Olkusz-Zawiercie Mining Area. This resulted in the shrinkage of water resources in the aquifer and there has been a change in the natural direction of groundwater flow from NW-SE to SE-NW. Periodical oscillations of the water table (first a decrease, then an increase) were an effect of natural changes due to the occurrence of a considerable shortage of precipitation in the periods of 1978-1984 and 1987-1993. Compared to the mean annual precipitation rainfall was lower by as much as 200 mm (Maciejowski 2000). The lowering of the water table was locally reinforced by the operations of quarries using the blasting technique (e.g. at Dubie and Dębnik). Strong shocks of the karstic rock masses caused the number of fractures to increase and an escape of groundwater downwards (Sawicki i Gutry-Korycka 1993, Maciejowski 2000). In the neighbourhood of the quarry at Dubie the water table dropped by 15 m (Maciejowski 2000). Simultaneously in points scattered thorough the area of the Upland several cones of depression formed due to the exploitation of groundwater for communal purposes.

The vanishing of small and middle-sized springs and a considerable variability in time of the discharge of middle-sized and large springs is an effect of several overlapping reasons. It is connected with:

- vanishing of supply from the groundwater system, being a result of the lowering of the water table due to anthropopressure and/or a simultaneous lack of precipitation,
- burying due to construction activities (Chełmicki ed. 2001, Chełmicki et al. 2001),

- destruction of spring alcoves in the areas occupied by quarries,
- lateral erosion of streams, channel changes (Partyka 2001) or accumulation of silt during large freshets in humid periods (Maciejowski 1996, author's own observations and interviews).

The observed variability of spring discharges is, first of all, an effect of climatic fluctuations and changes in the supply of water from precipitation (rain in summer, snow in winter), but also, to a large extent, of human activity (changes in the supply from aquifers, drinking water intakes). An interesting fact is the appearance of several new springs during this time, connected with local, spontaneous outflows of water in the vicinity of quarries (e.g. on the floor of the Racławka valley) or the formation of entirely new spring alcoves, in the neighbourhood of old, destroyed ones.

Disappearance of small streams and shortening of river network as well as fluctuations in their discharges are results of the transformations described above. The flow regime of surface waters has been destabilized also by the change of groundwater flow resulting from the lowering of the water table as well as gradually decreasing precipitation sums, which for a long time (1968-1984 and 1987-1993) determined a decrease tendency of discharge, whereas since 1994 they have definitely slowed it down. A complete disappearance of several streams is an effect of the lowering of the water table and the drying out of their springs (upper sections of rivers in the drainage basins of the Przemsza, Racławka, Szklarka and Sanka rivers). In most cases the cause was human activity, while to a smaller degree, rainfall supply. The lowering of discharges caused a periodic disappearance of flood-type freshets, and it was not until the abundant precipitation of 1997 and 1998 when such phenomena occurred. This situation had a substantial influence on the functioning of landforms (changes in the strength of the action of fluvial processes) and vegetation (disappearance of species connected with pure spring waters). A proof of that is the destruction of natural sites of *Cochlearia polonica*, an endemic plant formerly growing in presently dry spring of the Biała, in the drainage basin of the upper Przemsza (*Figure 5*).

Figure 5. Cochlearia polonica is endemic to Poland. This species died out at its natural locality. Today it persist in three transplant sites.

Degradation of the quality of surface and subsurface waters is an effect of a range of overlapping causes, natural and anthropogenic. Transformations in the quality of surface waters were induced by:

- dumps of communal waste from households, connected with lack of sewage system,

- littering of spring alcoves, floodplains and/or river channels directly (e.g. Dłubnia, Racławka, Szklarka), resulting from a lack of waste removal system or its weak performance until recently (Maciejowski 1996, Różkowski 1996, Chełmicki et al. 2001),
- location of towns and large villages along streams (np. Krzeszowice, Sułoszowa, Szklary, Czubrowice), and development makes for an increased mineralization (Chełmicki ed. 2001),
- location of major tarmac roads, supplying a large load of contamination, including oil-derived substances and heavy metals, along river channels (Maciejowski 2003),
- farming making for a considerable increased concentration of sulphate, potassium, calcium, nitrogen and phosphate ions.

Changes in the quality of groundwater, in turn, were caused by the following factors:

- areal contamination by nitrates and partly phosphates (Różkowski 1996, Siwek 2001, Chełmicki ed. 2001) coming from farming,
- chemical fertilization being a major source of phosphorus, sulphur and heavy metals (Chełmicki ed. 2001),
- pollution from rainfall making for changes in the pH of water (Chełmicki ed. 2001),
- communal waste landfills and large animal farms, mainly swine and poultry (Maciejowski 2003).

6. Conclusions

The conducted field research and the information obtained from the existing literature concerning the presented problem allow to formulate of the forthcoming conclusions:

1. changes in water conditions in the southern part of the Kraków-Częstochowa Upland over the past 40 years have been a result of the overlapping of numerous natural and anthropogenic causes, mutually strengthening or weakening the effects of their occurrence,
2. the observed transformations may be divided into two groups: fluctuation transformations (decrease-increase-decrease) largely controlled by natural factors (mainly climate) and durable transformations with a clear negative tendency, connected with human activities (e.g. the slow lowering of the water table and the disappearance of a part of springs, independently of the fluctuations of supply from precipitation),
3. changes being the most serious in results, i.e. the lowering of the water table and the contamination of water resources originated due to causes resulting directly or indirectly from the ways of economic activity carried out by man – mining, manufacturing and farming,
4. there is a range of changes evoked by man, results of which are no longer reversible, amongst others burial of springs or changes in the direction of the flow of groundwater streams,
5. an intensified anthropopressure expected in the years to come, particularly an intensification in farming, with no attention paid to the results of already occurred transformations and without attempts of gradual reduction of their causes, may result in a further deterioration of the state of things,
6. a consequence of that may be a further shrinkage of drinking and industrial water resources for the inhabitants of Kraków and its surroundings, who use the resources.

Acknowledgements

The author thanks Dr. Andrzej Kacprzak for the translation of the paper.

References

- Atlas of Poland, vol I. (2001) Mydel, R. (ed.), Fogra, Kraków. (in Polish)
- Chełmicki, W. (2001) *Water. Resources, degradation and protection*, PWN, Warszawa. (in Polish)
- Chełmicki, W. ed. (2001), *Springs of the Kraków-Wieluń and Miechów Uplands. Changes between 1973 and 2000*, IGiGP UJ, Kraków. (in Polish, with English summary)
- Chełmicki, W., Baścik, M., Korska, A., Pociask-Karteczka, J., Siwek, J., Żelazny, M. (2001) Comparison of the state of springs in the Cracow-Wieluń and Miechów Uplands in 1973-1974 and 1999-20000, in German, K. and Balon, J. (eds.), *Transformations of the natural environment of Poland and its functioning*, Problemy Ekologii Krajobrazu X, IGiGP UJ, Kraków, pp. 383-388. (in Polish, with English summary)
- Dynowska, I. (1993) Foreword, in Dynowska, I. (ed.), *Transformations in water conditions in Poland due to natural and anthropogenic processes*, Wyd. UJ, Kraków, pp. 354 - 371. (in Polish)
- Dynowska, I., Dynowski, J. (1980) *Hydrology exercises for hydrologists*, Skrypty uczelniane UJ, 358, Kraków. (in Polish)
- Hydrogeologic Map of Poland. Ark. Kraków (1986) Różkowski, A. (ed.), Wyd. Geol., Warszawa.
- Instruction for the development of Hydrographic Map of Poland 1:50 000 (1964) Wit-Jóźwik, K. (ed.), IG PAN, Warszawa. (in Polish)

- Kundzewicz, Z.W. (2000) *If a small amount of water... Water resources for sustainable development*, PWN, Warszawa. (in Polish)
- Maciejowski, W. (1996) Changes in water conditions on example the Racławka and Szklarka drainage basins (south Cracow-Częstochowa Upland) in years 1964-1993, Symposium Proceedings *"Environmental changes dynamics influence by anthropopressure"*, AP, Kraków, pp. 84-86. (in Polish)
- Maciejowski, W. (2000) Changes in water conditions in the Racławka and Szklarka drainage basins in 1933-1998, *Prace Geograficzne*, 105, pp. 257 - 286. (in Polish, with English summary)
- Maciejowski, W. (2001a), Model of natural environment changes in the catchment of the Rudawka, the Cracow Upland, in German, K. and Balon, J. (eds.), *Transformations of the natural environment of Poland and its functioning*, Problemy Ekologii Krajobrazu X, IGiGP UJ, Kraków, pp. 375-382. (in Polish, with English summary)
- Maciejowski, W. (2001b) Model of water conditions changes in the Racławka and Szklarka drainage basins the Cracow Upland, Conference Proceedings**,** Kielce, pp. 72-73. (in Polish)
- Maciejowski, W. (2003) Causes and effects of the water conditions' changes in Cracow Upland, in Lach, J. (ed.), *Environmental changes dynamics influence by anthropopressure*, AP, Kraków, pp. 61-67. (in Polish, with English summary)
- Mannion, A.M. (2001) *Global Environmental Change A Natural and Cultural Environmental History*, PWN, Warszawa. (in Polish)
- Milkow, F.N. (1981) *Physical geography - contemporary estate, regularities and problems*, Izd. Woroneżskowo Uniwersiteta, Woroneż. (in Russian)
- Partyka, J. (2001) Transformations of the natural environment in the Ojców National Park over the past 25 years (1975-2000), in German, K. and Balon, J. (eds.), *Transformations of the natural environment of Poland and its functioning*, Problemy Ekologii Krajobrazu X, IGiGP UJ, Kraków, pp. 366-374. (in Polish, with English summary)
- Różkowski, J. (1996) Transformation in chemical composition of karst water in the southern part of the Cracow Upland (Rudawa and Prądnik drainage areas), *Kras i speleologia*, spec. 1, pp. 1-106. (in Polish, with English summary)
- Sawicki, J., Gutry-Korycka, M. (1993) The impact of mining on the circulation of water, in Dynowska, I. (ed.), *Transformations in water conditions in Poland due to natural and anthropogenic processes*, Wyd. UJ, Kraków, pp. 354 - 371.
- Siwek, J. (2001) Human impact on nitrate and phosphate concentrations in spring water in the drainage basins of the Prądnik, the Dłubnia, and the Szreniawa, in German, K. and Balon, J. (eds.), *Transformations of the natural environment of Poland and its functioning*, Problemy Ekologii Krajobrazu X, IGiGP UJ, Kraków, pp. 397-401. (in Polish, with English summary)
- Soja, R. (1997) Hydrologic description of the Prądnik River catchment area within the boundaries of the Ojców National Park, parts A and B, Kraków, Bibl. OPN, manuscript. (in Polish)
- Synowiec, K., Główka, A., Cieśla, G., Reczek, T. (2007) *Classification of running waters in the province of Małopolskie in 2006*, 2007, Voivodship Inspectorate for Environmental Protection in Kraków, Kraków. (in Polish)
- *The State of the province of Małopolskie Environment in 2006*, 2007, Voivodship Inspectorate for Environmental Protection in Kraków, Kraków. (in Polish)
- Tyc, A. (1997) Anthropogenic impact on karst processes in the Silesian-Cracow Upland (Olkusz-Zawiercie area as example), *Kras i speleologia*, spec. 2, pp. 1-175. (in Polish, with English summary)