Andrzej BOGDAŁ, PhD

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SUMMARY
OF PROFESSIONAL ACCOMPLISHMENTS

WITH ELEMENTS OF CV
AND DESCRIPTION OF A MONOTHEMATIC PUBLICATION CYCLE

Krakow, March 2016

1. PERSONAL DATA

Name and surname of habilitation candidate:	**Andrzej BOGDAŁ, PhD**
Date and place of birth :	**14.07.1973, Krynica-Zdrój, Poland**
Employed by:	**University of Agriculture in Krakow,** **Department of Land Reclamation and Environmental Development** **al. Mickiewicza 24/28, 30–059 Krakow**

2. EDUCATION

Sep. 1988 Jun.1993	Electrical technician – Railway Technical School in Nowy Sącz completed with distinction.
Oct. 1993 Jun. 1998	MSc. in Environmental Engineering – uniform Master studies at the Faculty of Environmental Engineering and Land Surveying, Agricultural University in Krakow, in the field of Environmental Engineering.
13 Oct. 2004	Doctor of Agricultural Sciences in the field of Environmental Development conferred by the Agricultural University in Krakow, Faculty of Environmental Engineering and Land Surveying.

OTHER FORMS OF EDUCATION

Oct. 1999 Jun. 2001	Course of English at the Foreign Languages College, Jagiellonian University in Krakow – 2 certificates.
Oct. 2008	A one-week didactic and research traineeship in Thuringia, Germany under the framework of EU Lifelong Learning Programme, Leonardo da Vinci project: "*Modern academic education the field of water and sewage management in rural areas*" – certificate.
Oct. 2010	A one-week didactic and research traineeship in Thuringia, Germany under the framework of EU Lifelong Learning Programme, Leonardo da Vinci project: "*Water management in rural areas. Water Directive*" – certificate.
Oct. 2011 Jun. 2012	Pedagogical training study for academic teachers at Pedagogy and Psychology Centre of the Cracow University of Technology – diploma.
Oct. 2013 Feb. 2014	Traineeship at Marcin Golonka Design Studio in Nowy Sącz, under the framework of a project *"Knowledge, practice, cooperation as a key to success in business"* co-financed by the European Union under the framework of Human Capital Operational Programme, Sub-measure 8.2.1 support for the cooperation of research and business – certificate.
Dec. 2014	"*Activating teaching methods using IT tools"* workshop realized as part of project "*Strengthening the didactic potential of University of Agriculture in Krakow"* co-financed by European Social Fund – certificate.

3. HISTORY OF EMPLOYMENT

Oct. 1998 Jul. 2005	Agricultural University in Krakow – research assistant at the Department of Land Reclamation and Environmental Development, Faculty of Environmental Engineering and Land Surveying.
Aug. 2005 to date	Agricultural University (present: University of Agriculture) in Krakow –

	adjunct at the Department of Land Reclamation and Environmental Development, Faculty of Environmental Engineering and Land Surveying.

4. RESEARCH

Jun. 1998	Defence of Master thesis entitled: „*Spatial variability of physical-and-water and physicochemical soil properties on experimental plots in Chełm near Krakow*" – supervisor Professor Krzysztof Boroń. The thesis won the Professor Franciszek Hendzl Award granted by the Water and Land Reclamation Engineers and Technicians Association.
18 May 2001	Opening of the Doctoral Procedure by the Faculty of Environmental Engineering and Land Surveying Council – the supervisor: Habilitated Doctor Krzysztof Ostrowski.
13 Oct. 2004	Public defence of the doctoral dissertation entitled: „*The impact of agriculture and rural settlement on surface water quality in sub-mountain micro-catchments*" – supervisor: Habilitated Doctor Krzysztof Ostrowski, reviewers: Professor Stanisław Kostrzewa and Professor Włodzimierz Rajda. On a proposal from the reviewers the doctoral dissertation received distinction from the Faculty Council.

5. ACHIEVEMENTS IN THE AREA OF SCIENTIFIC RESEARCH ACTIVITIES

My scientific, implementation and engineering output comprises 133 items, including 53 published peer-reviewed scientific papers [att. 4: A.1.1–A.1.4; B.1.1–B.1.8; B.2.1–B.2.41], 9 popular science publications [at: 4: A.2.1–A.2.2; B.3.1–B.3.7] and 71 unpublished papers [Master thesis; doctoral dissertation; A.4.1–A.4.9; A.5.1–A.5.32; B.5.1–B.5.11; B.6.1–B.6.17]. These are mainly joint works, of which 53 original papers and 9 popular science papers were published in 21 scientific journals (two of them simultaneously in Polish and English) of which 17 papers were published in English (Tab. 1). Total score for original papers (according to MNiSW) is 394 (Tab.2), of which 144 points are my individual contribution (until 29 February 2016).

During the period **before receiving the doctor degree** my scientific output consisted of 4 peer-reviewed published papers [att. 4: A.1.1–A.1.4] and two popular science papers [att. 4: A.2.1–A.2.2], as well as 43 unpublished works [4: Master thesis; doctoral dissertation; A.4.1–A.4.9; A.5.1–A.5.32]. Total score for original papers in this period was 8.

After receiving the doctor degree my scientific and research output increased by 56 published works, of which 49 are original peer-reviewed papers published in scientific journals [att. 4: B.1.1–B.1.8; B.2.1–B.2.41] and 7 popular science ones [att. 4: B.3.1–B.3.7]. At that time the number of my points, according to MNiSW scores increased by 386. Out of my original papers, 5 were published in the journals indexed in the Web of Science Base (WoS) and 4 of them are on the list of Journal Citation Reports (JRC) with an Impact Factor. Two positions are individual papers [att. 4: B.1.5; B.3.3]. I am the co-author of 3 monographs, including two issued simultaneously in Polish and English, devoted to water quality in small catchments situated in the Malopolskie province, where construction of small retention reservoirs was planned [att. 4: B.1.1; B.1.2; B.1.3] and a 1 monograph on natural and hydrochemical conditionings of revitalization of the Chechło water reservoir situated in the Trzebinia district [att. 4: B.2.33].

Table 1. Concise list scientific, implementation and engineering achievements

Detailed description	Before obtaining a doctoral degree	After obtaining a doctoral degree	Total
Publications:			
– original research papers based on own research	4	49	53
– popular science articles	2	7	9
Total:	**6**	**56**	**62**
Including publications:			
– in English	1	16	17
– in other congress languagess	–	–	0
– in the proceedings of international conferences	–	4	4
– as the only author	–	2	2
– monographs, books, scripts	–	4	4
Unpublished works:			
– dissertations	2	–	2
– final reports from long-term studies	6	7	13
– design works, expert analyses, research calls	34	20	54
– grants	1	1	2
Total:	**43**	**28**	**71**
All works:	**49**	**84**	**133**

I presented my research results as 29 oral reports and at 18 poster sessions at 14 international conferences and 30 national seminars and conferences [att. 4: Z.1.1–Z.1.2; Z.2.1–Z.2.42]; of which 27 reports and 18 posters I presented after receiving the doctor degree. I am the co-author of 54 project works, expert opinions and commissioned research projects [att. 4 and 6: A.4.8–A.4.9; A.5.1–A.5.32; B.5.9–B.5.11; B.6.1–B.6.17], 13 reports on the realization of annual and multiannual own research and statutory projects [att. 4 and 5: A.4.1–A.4.6; B.5.1–B.5.7], as well as 2 final reports from the research projects financed by the National Committee for Scientific Research (KBN) [att. 4 and 6: A.4.7] and the Ministry of Research and Higher Education (MNiSW) [att. 4 and 6: A.5.8].

According to Web of Science base (WoS) my published articles were cited 10 times. My H Index (Hirsch index) is 1. Summary Impact Factor (IF) for my publications according to the Journal

Citation Reports list (KRC) is 1.926. However, according to Google Scholar my published articles were cited 125 times, and the H Index is 6 (until 29 February 2016).

I have reviewed manuscripts for the Acta Scientiarum Polonorum – Formatio Circumiectus series, on the list B of MNiSW.

By the resolution of the Faculty Council of Environmental Engineering and Land Surveying I was appointed an auxiliary supervisor for the final stage of the doctoral thesis entitled: "*The impact of deep soil loosening on some physical-and-water properties of arable soils".*

Table 2. Research output according to point-based evaluation of scientific journals list by the Ministry of Science and Higher Education (MNiSW)

Journal	Language of publication[1]	No of papers	IF	Points acc. to MNiSW[2]	
				For ind. journal	Total
Scientific journals in Journal Citation Report (JCR) base and indexed in Web of Science base					
Polish Journal of Environmental Studies	A	1	0,600	15	15
Annual Set The Environment Protection	P	3	0,442	15	45
Scientific journals not listed in Journal Citation Reports (JCR) but indexed in Web of Science base					
Portfolio of the Environmental Protection and Development Committee PAS	A	1	–	4	4
Journals without Impact Factor (IF) and not indexed in Web of Science base					
Research Journal of the University of Agriculture in Krakow – series: Environmental Engineering	P	4	–	4	16
Journals of the Geodesy and Cartography committee PAS	P	1	–	0	0
Acta Scientiarum Polonorum – series: Formatio Circumiectus	P A	7 3	–	4/5/10 4	36 12
Electronic Journal of Polish Agricultural Universities – series: Environmental Development	A	1	–	4	4
Regional Bulletin of the Agricultural Extension Department, Agricultural University in Krakow	P	1	–	0	0
Annals of the Agricultural University in Poznań – series: Land Reclamation and Environmental Engineering	P	1	–	4	4
Acta horticulturae et regiotecturae (Slovakia)	A	1	–	2	2
Water-Environment-Rural Areas	P	2	–	4	8
Advances of Agricultural Sciences Problem Issues	P	7	–	4/6	36
Advances of Agricultural Sciences	P	1	–	6	6
Ecological Engineering	P	3	–	0/9	9
Gas, Water and Sanitary Techniques	P	7	–	4/9/6	46
Slovak University of Agriculture in Nitra, zbornik recenzovaých vadeckých prác na CD nosiči	A	4	–	2	8
Periodical of the University of Agriculture in Krakow	P	1	–	0	0

CD edition of the University of Agriculture in Krakow	P	4	–	0	0
Monographs in Polish and English. University of Agriculture	A P	2 2	–	25 20	90
Journal of Ecological Engineering	A	4	–	12	48
EPISTEME: Scientific and cultural journal	P	1	–	5	5
Total:		62	1,926	–	394

[1] P – Polish, A – English; [2] score of the MNiSW in compliance with the publication year

5.1. Directions of research and scientific achievements before receiving the doctor degree

My research activities are strictly connected with the investigations conducted at the Department of Land Reclamation and Environmental Development of the University of Agriculture in Krakow. I have conducted a majority of my works in research teams, which was due to their complexity and interdisciplinary character. During the period before a doctoral degree I was involved in:

– **assessment of the concentrations and loads of physicochemical components carried into the catchment area with atmospheric precipitations [A.1.1],**
– **assessment of the environmental impact of the existing water and land reclamation installations and the purposefulness of constructing new ones [A.4.8],**
– **research on physicochemical properties of rainwater and runoffs from the catchments with forest and suburban land use [A.1.2; A.1.3].**
– **bioengineering for channel bank armouring [A.1.4; A.2.2].**

The first direction of research and publications which I followed before the doctoral degree was **the assessment of concentrations and loads of physicochemical components carried into the catchment area with atmospheric precipitations**. Rainwater contains various kinds of admixtures composed of organic and inorganic substances and gases which dissolve in these waters when they occur and contact with the outer environment. Intensive civilizational development over the last decades led to intensive emission of harmful dusts and gases into the atmosphere. Emitted components are carried in the air, sometimes for considerable distances and then return to the earth surface with precipitations. Falling down in the form of solutions, solid residues and aerosols, they contribute to agricultural areas pollution. The aim of the investigations [A.1.1] was an assessment of spatial and time diversification of concentrations and loads of selected physicochemical components carried with the precipitations to the area of three experimental microcatchments located in the Wadowice district in the Malopolska province and differing with their altitude location, management and distance from the city.

Yearly investigations were conducted in the elementary catchments of the Wieprzówka river: 1) “Barnczak” agricultural microcatchment situated in Wieprz district, about 4 km north of Andrychów city, with slopes of north-western aspect, on average situated at the altitude of 338 m a.s.l; 2) “Krakowica” urbanised microcatchment situated in Andrychów district and directly adjoining the city to the north-east, with slopes of northern and north-western exposure, on average situated at the altitude of 359 m a.s.l.; 3) “Rzyki-Jagódki” microcatchment, situated in Andrychów district, about 9 km south of Andrychów city, has slopes with north-western and north-eastern exposure, on average situated at the altitude of 706 m a.s.l. One Hellman pluviometer was placed in each of the catchments and a rainwater collecting catcher, composed of a 1.5 dm^3 rain bowl, was installed in its vicinity. On site pH values were measured ongoing, whereas the concentrations of: ammonium ($N–NH_4^+$) and nitrate nitrogen ($N–NO_3^-$), phosphates (PO_4^{-3}), iron ($Fe^{+2/+3}$), sulphates (SO_4^{-2}), chlorides (Cl^-) and manganese (Mn^{+2}), total suspended solids and total dissolved solids were determined in a laboratory in $mg \cdot dm^{-1}$ using standard methods. The component loads were computed as a product of the precipitation volume in dm^3 per one hectare area and component concentrations in $mg \cdot dm^{-3}$ in the collected sample and then converted into $kg \cdot ha^{-1}$. The values of partial loads computed in this way were summed up receiving in this way annual loads and loads in the individual seasons of the year.

On the basis of the empirical data analysis [A.1.1] it was established, that average annual concentrations of most investigated chemical components in the rainwater in all analysed microcatchments were lower than the admissible normative values for class I water, but due to a lack of the normative values for rainwater at that time, the values permissible for surface waters were implemented [Rozporządzenie… 1991]. The exception were concentrations of ammonium nitrate and manganese, which classified water to class II, and due to low pH, water in “Krakowica” and “Rzyki-Jagódki” microcatchments was classified to class III. Concentrations of $N–NH_4^+$, $N–NO_3^-$, $Fe^{+2/+3}$, SO_4^{-2}, Cl^-, total soluble solids and pH values reached the highest values in the microcatchment situated the lowest above the sea level, lower in the microcatchment located higher and the lowest in the mountain microcatchment situated near 350 m higher than the other two. In case of Mn^{+2} the regularity was the opposite, moreover the highest concentrations of total suspended solids were registered in the mountain microcatchment. On average for three microcatchments, the lowest values of the analysed components concentrations were observed in summer months, whereas the highest in winter and spring months. The exception were phosphates, whose concentrations were the lowest in winter months and the highest in summer. The loads carried with precipitations were small for most of the components and depended more on the concentrations than on precipitation height. Regarding the components significant for the environment and agriculture, over a dozen kilogram amounts of $N–NH_4^+$ and $N–NO_3^-$ and many dozen kilogram loads of SO_4^{-2} were observed carried to the catchment area over a year. A considerable deposition of suspended and dissolved solids was also registered [A.1.1].

Cognitive presumptions following from my research state that atmospheric precipitations are important source of nitrogen and sulphur and this fact should be taken into consideration at preparing fertilizer balance on agricultural farms. Moreover, I found out, that spatial distribution of physicochemical properties of precipitations does not result only from the vicinity of the catchment and pollution emitters (e.g. city), but is also shaped by the direction in which the polluted air masses move.

The other direction of research, in which I was actively engaged was **assessment of the environmental impact of the existing water and land reclamation installations and the purposefulness of constructing new ones.** The aim of the research [A.4.8] was evaluation of the current state of soil-water relationships in a part of the Middle Nida river valley, regarding the agricultural land use and determining the impact of previously installed land reclamation appliances on the natural environment of the adjoining areas.

Investigations covered 643 h area of the right bank of the Nida river valley, where in the years 1988–1997 the 1st stage of land reclamation installations was completed, designed within the Nida-Pińczów-Motkowice IVA–VII investment. The eastern border of the object was the Nida river along the reach from km 75+700 to km 81+500, where its course is arched and in the lower part, along the length of about 3 km the channel is regulated. The closing point of the object southern border was a bridge joining Sobowice and Skowronno. The northern border of the area was delimited by the water intake for Gravity Flow Channel I, while the western border was mainly delimited by the building alignment of Stawy, Chojny and Sobowice villages. The area is a part of administrative Imielno district, situated in Jędrzejów county, in Świętokrzyskie province. Despite ussually difficult soil and water conditions, agricultural land use dominates in the analysed area – grasslands cover about 70%, in which meadows cover the area of 302.6 ha, i.e. 47% of the whole studied area, whereas pastures cover 146.6ha (22.8%). Arable land with dominant soils in IV and VI soil quality class cover the area of 151.2 ha, i.e. 23.5%. The remaining area – 42.2 ha is covered by wastelands, land under water and roads. Research works started with the site inspection, during which the boundaries and methodology of field works were stablished. The second stage involved appointing 6 research cross sections and installation of 20 piezometer wells for measuring groundwater table. The installed wells were the basis for the localisation of soil and vegetation studies. Guided by their localisation we made 20 full soil pits from which soil material was sampled for laboratory tests. The results of conducted inventory of the object use were mapped in 1:5000 scale and presented numerically in tables. Registration of plant communities was conducted by means of Braun-Blanquet method, making 20 phytosociologal relevés within the uniform, representative and most frequently occurring communities of plant patches in the immediate vicinity of the wells. In order to determine the relative position of groundwater table and water stages in the Nida river, the necessary levelling measurements of the cross sections were made, on which points with installed control wells were marked. Moreover, measurements of daily height of precipitations were conducted in Motkowice village by means of standard Hellman pluviometer.

On the basis of conducted investigations [A.4.8] it was stated that mainly alluvial soils, degraded chernozems and organic soils represented by peat moor, mucky and peat-muck soils occur in the vicinity of Nida-Pińczów-Motkowice IVA–VII object. A general regularity was established basing on the analysis of the dynamics of groundwater location in the cross sections and control wells, which showed that at the assumption of exclusive use of the analysed object as meadowland, average depth of ground water table during autumn-winter-summer seasons on the investigated object were mostly above or on the limit of minimum drainage standard. On the other hand, during the vegetative period they fell below the drainage standard. There were places on the researched object where groundwater table lay below the maximum norm, also during the non-vegetative period. It demonstrates, that maintaining moisture content in soil, appropriate for meadows would require efficiently functioning drainage-irrigation systems. Drainage acting one-sidedly may be allowed only on degraded chernozem complexes in case of the change in the land use from meadow to arable lands. Phytosociological relevés were quite well correlated with the actual soil moisture on this terrain. They demonstrated that a definite part of the valley, particularly its central part reveals excessive moisture content, as evidenced by the occurrence of plant communities with dominant reed and reed grass. The areas covered by these communities will require further regulation of water regime using land reclamation technologies to make possible appropriate meadow farming. Only the most interesting, from the environmental point of view plant communities, in which purple moor grass, *Sesleria albicans* or a protected species, such marsh gentian will require preservation of the "status quo", since each change connected with technical activities would lead to floristic changes causing a disappearance of the species mentioned above [A.4.8].

Conducted research allowed to make a sustainable assessment concerning the impact of the existent and purposefulness of constructing new land reclamation installations. The novelty of these investigations conducted by the end of the nineties consisted of the fact, that I identified agricultural soils requiring an improvement of air and water relations using technical means, but at the same time I called the attention to the delineating the areas which should be protected due to precious plant species which occur there and which in many cases are refuge for birds and animals.

My scientific activities comprised also research on **research on physicochemical properties of rainwater and runoffs from the catchments with forest and suburban land use.** I conducted research works for two years in the area of two microcatchments: "Jagódki" [A.1.2] and "Krakowica" [A.1.3]. The aim of the investigations was determining the range of values and seasonal variability of some physicochemical indices concentrations in the surface and rainwater.

Both investigated catchments are situated in the Beskid Mały Mts., in Andrychów district. The main watercourse draining "Jagódki" microcatchment is a left bank tributary of the Rzyczanka river, which is an extension of the Wieprzówka river. Due to the hypsometry (about 505-918 m a.s.l) it is a mountain catchment. Forests cover about 93% of its area, the rest is under grasslands and roads, whereas arable lands are almost absent. Location at the altitude of between 318 and 487 m a.s.l. and the terrain use (incl. 30.7% built up area, 46.2% of agricultural lands and 15.6% of forests) indicate a sub-mountain and suburban character of “Krakowica” microcatchment. The research programmes comprised once a month determining of 10 (“Jagódki”) and 14 (“Krakowica”) physicochemical properties of the runoff and rainwater. In both microcatchments pH and concentrations of $N–NH_4^+$, $N–NO_3^–$, $PO_4^{3–}$, $Fe^{2+/3+}$, $SO_4^{2–}$, $Cl^–$, Mn^{2+}, total suspended solids and total dissolved solids were assessed by standard methods, whereas electrolytic activity $N–NO_2^–$, Na^+ and K^+ were determined additionally only in „Krakowica”. Samples of surface water were collected directly from the watercourses at hydrometric stations, the rainwater was sampled from the catchers located in the vicinity of Hellman pluviometers. The results were compared with the values permissible for water quality classes obligatory at that time in Poland [Rozporządzenie…1991].The data were analysed separately for the periods of the year for which, like for the whole period of research, mean values of physicochemical features of both waters were calculated. Differences between mean values of the same indices assessed in rainwater and runoff water were estimated by means of t-Student test.

On the basis of results of research conducted in “Jagódki” microcatchment [A.1.2] it was found that from among the analysed indices, concentrations of $Fe^{2+/3+}$, $SO_4^{2–}$, $Cl^–$ and total dissolved solids did not affect the worsening of either rainwater or runoff water quality. Moreover, nitrate nitrogen concentration in the rainwater and ammonium nitrogen concentration in the runoff water allowed to classify them to purity class I. Total suspended solids concentrations had the worst effect on water quality and at some dates qualified both rainwater and surface water to unclassified ones. Among the analysed indices only mean concentrations of $Fe^{2+/3+}$, Mn and total suspended solids did not differ significantly between the investigated waters. Higher concentrations of $N–NH_4^+$ and $PO_4^{3–}$ but significantly lower $N–NO_3^–$, $SO_4^{2–}$, $Cl^–$ and total dissolved solids were registered in the rainwater and the regularity was observed in each of the seasons of the year. Moreover, rainwater had a much lower pH in comparison with the runoff water. No marked differences were noted in the rainwater between the mean values for the winter and summer half-year, whereas in the surface water on average higher concentrations of $N–NO_3^–$ and Mn^{2+} were noted in the winter half-year.

The studies conducted in “Krakowica” microcatchment revealed, that rainwater contained significantly less of components than runoff water, except some biogens ($N–NH_4^+$ and $PO_4^{3–}$). Both kinds of water were unclassified, which was determined by high concentrations of $PO_4^{3–}$, $N–NO_2^–$ and total suspended solids, in rainwater also its pH, whereas Mn^{2+} concentrations in surface water. Concentrations of ammonia and nitrogen form of nitrogen were on the level classifying the analysed waters to purity classes III and II. Higher concentrations of a majority of analysed features in rainwater were registered in the vegetative period, whereas in the runoff water markedly higher $N–NO_3^–$ and $SO_4^{2–}$ concentrations were observed in the non-vegetative period [A.1.3].

I demonstrated a much lower pH of rainwater than runoff water in both catchments and confirmed the opinion, that precipitations play an important role in acidification and leaching of soils.

Moreover, I stated that precipitations are an important source of ammonium nitrogen and phosphates inflow to a catchment. I did not observe unanimous seasonal regularities in the rainwater, but surface waters contained significantly higher amounts of nitrate nitrogen in the winter half-year.

Moreover, before a doctoral degree I was investigating **bioengineering for channel bank armouring.** Systems of mountain streambed armouring by means of stage and step correction and bank fortification by planted vegetation were implemented in Poland over the last several dozen years. The use of natural armouring is now much less popular method of stream and river banks protection. A mixed stage-drop structure system coupled with plant covering was used also in the seventies when the Mszanka stream was trained. It aimed at enabling a free water flow, channel stabilisation, inhibiting bottom and bank erosion and limiting the bedload movement. The training was also supposed to protect the areas of adjoining farms, engineering structures (roads and bridges) and provide convenient conditions for recreation. The investigations conducted in the years 2001–2002 [A.1.4; A.2.2] aimed to assess the current state of vegetal cover after 28 years from the streambed regulation and after 24 years from the introduction of natural armouring.

The studies on plant communities on the Mszanka banks were conducted along the km 5+039 to 5+724 reach, below the debris dam closing the systematic stage and drop structure correction of the lower and middle stream course. Floristic and phytosiociological studies were carried out in the area of four strips among the levelling cross sections delineated in the middle of the distance between the drop structures the drop structure and debris dam, where the vertical structure of vegetation was assessed, all vascular plant species were inventoried, their quantitative features and sociability were assessed by Braun-Blanquet method and edaphic requirements by means of ecological indicator numbers suggested by Zarzycki, and finally also the projective land cover by herb plants in the cross-section line using Kostuch method. The studies on plant communities were preceded by the characterisation of physical and chemical properties of the topsoils in the middle of riverbed and by the riverbed strips in all cross-sections and on the bedload carried by the water [A.1.4; A.2.2].

On the basis of the conducted research results it was established, that diversified and well developed vegetal cover of the Mszanka channel armouring properly protects the banks against scouring, both at low and high water stages. No major traces of ground surface erosion were observed in the full vegetation period. Only some of the ornamental tree and shrub species, which were introduced as an experiment in the seventies survived, which indicates their poor usefulness for reinforcing the Mszanka stream banks. Planting *Forsythia intermedia* and *Caragana arborescens* under local site conditions proved a mistake as these plants require dry and airy soils, similarly *Chaenomeles japonica* requiring careful tending, in the first place regular shoot cutting and de-weeding. Considering the trees and shrubs, black elder, bird cherry, cornus sanguinea, ash, blackberry, gray alder, blackthorn, false accacia, black poplar, white and purple willow and osier were growing best on the banks along the analysed Mszanka reach. These species should be recommended for the armouring of streambeds in the areas of similar habitat conditions. A good way to additional protection of the ground against erosion on the freshly formed bank scarps may be acceleration of creation of new herb plant succession period by planting common butterbur and sowing grass seeds, the best would be orchard grass and perennial ryegrass, as well as white and meadow fescue, which were also growing well on the Mszanka banks. Maintaining the natural armouring of the Mszanka river bank in good condition will depend on the tending measures. These should include pruning shrubs, which will ensure the conditions for more profuse growth of herb plants which best protect the soil against erosion [A.1.4; A.2.2].

Results of my research conducted in the Mszanka catchment are applicable, since they provide the designers with important information concerning the plant species which proved a right choice over a long period of engineering practice and therefore should be uses for pro-ecological protection of riverbed banks on a wider scale.

5.2. Directions of research and scientific achievements after a doctoral degree

After receiving my doctoral degree I continued research on the quality of rainwater and surface water, starting the investigations in new areas. During that period I focused my research on the following issues:

- **the impact of built up areas on quality parameters of surface water [B.2.1; B.2.3; B.2.32],**
- **analysis of water self-purification processes in the catchment under breeding pressure [B.2.12; B.3.2],**
- **hydrological and hydrochemical regime in the small uncontrolled agricultural submountain catchments [B.2.2; B.2.4–B.2.10; B.2.14; B.2.17; B.2.21],**
- **initial hydrochemical assessment of conditionings for localisation of small retention reservoirs planned in the Malopolskie province [B.2.11; B.2.13; B.2.15; B.2.16; B.2.18; B.2.19],**
- **investigations on soil erosion potential in the catchment of planned water reservoir [B.2.24],**
- **innovative method of rainwater management [B.5.9],**
- **the impact of selected agricultural land reclamation measures on physicochemical soil properties [B.2.31; B.2.34],**
- **environmental and hydrochemical conditionings for revitalisation of Chechło water reservoir [B.2.33],**
- **studies on water and nutrient losses in the open drip irrigation system in large area greenhouses [B.2.35];**
- **quality changes of water flowing along the length of selected Malopolska rivers [B.2.28; B.2.36; B.2.41].**

During the first period of my research following the doctoral thesis defence I published the results of research connected with **the impact of built up areas on quality parameters of surface water.** The investigations addressing this issue were conducted on the Wieprzówka river flowing through Andrychów city, with 23 thousand inhabitants, situated in Wadowice county in the area of Malopolskie province. The whole length of the studied river is 27.6 km, of which a half in within the Andrychów district boundaries. It provides the main source of water for the city and district inhabitants and for the local industries. In its upper course it is susceptible to the effect of agricultural area pollution, whereas in the middle part to the infrastructure and industry of Andrychów city. Water was sampled every two weeks for two years in two measurement points situated beyond and below the city in order to determine the impact of urbanised area on changes of physicochemical features values in the Wieprzówka river. Water pH and electrolytic conductivity were measured on site, while in laboratory PO_4^{3-}, $N{-}NH_4^+$, $N{-}NO_2^-$, $N{-}NO_3^-$, SO_4^{2-}, Mn^{2+}, $Fe^{2+/3+}$, Cl^-, total dissolved solids, total suspended solids and dissolved oxygen were assessed using standard methods. The water quality was assessed by comparison of the obtained results with limit values of pollution for the inland surface waters [Rozporządzenie …1991]. On the other hand, the impact of urban infrastructure on the concentrations of analysed features in the studied Wieprzówka stream was determined statistically by means of parametric t-Student significance test. On the basis of conducted data analysis it was established, that the concentrations of ammonium and nitrate nitrogen and manganese, both above and below the city, classified the water to quality class III, whereas phosphate and nitrite nitrogen content, respectively to class II and III, but only above the city. The contents of dissolved oxygen and total suspended solids in both measurement points, phosphate and nitrite nitrogen – only below the city exceeded the standard values for class III water. All analysed physicochemical indices assumed less positive values below the city, which was proved statistically in 8 out of 13 analysed cases. A negative effect of urban built up area on water quality was best proved by phosphates and nitrite nitrogen, whose mean concentrations were not only significantly statistically higher below the city, but in result of urban anthropopressure led to worsening of water quality by one ($N{-}NO_2^-$), or even two classes – PO_4^{3-} [B.2.3].

I conducted similar investigations also in the Ropa river catchment [B.2.32] situated in the southern part of Poland, in the area of Gorlice, Tarnów and Jasło counties. The Ropa is a type 12 flysch stream, 78.7 km long. The river flows from its source in the slopes of Jaworzynka Mt, its outlet is at 105 km of the Wisłok river course. It is the source of water for the supply system water and simultaneously acts as purified sewage receiver for among others, Gorlice city. The Ropa river catchment is agricultural and forestry type, since respectively 43 and 44% of the area fall for these land use forms. In order to assess the impact of Gorlice city on the quality of river water, analysed were the results of three-year hydrotechnical research works conducted in two measurement points located in Szymbark and Biecz, respectively 3.8 and 6.0 km above and below the city. 24 physicochemical indices, 10 priority substances and 5 specific contaminants were determined in the water samples. Basic descriptive statistics were computed for all the indices and the statistical significance between the values of physicochemical indices determined in different measurement points were estimated by means of U Mann-Whitney test. The assessment of the quality and functional qualities was conducted on the basis of the obligatory legal acts [Rozporządzenie… 2011, 2002a and 2002b]. On the basis of research results analysis it was established, that the values of 6 out of 24 physicochemical indices were significantly higher in the Ropa water below the city. Above Gorlice the water had very good ecological state and could be used for consumption after a high performance physical water treatment appropriate for category A3 waters. On the other hand, below the city ecological state of the water worsened and was good, but regarding the microbiological state it did not meet the requirements for surface waters used for potable water supplies to people [B.2.32].

I conducted analyses on the built up area impact on water quality also in the Górka settlement and agricultural catchment. The watercourse draining this catchment is a right bank tributary to the Wieprzówka and flows at the distance of 150 from residential and farm building in Wieprz village. The area of the upper part of the catchment closed by a hydrometric cross section is 0.87 km^2 and the watercourse length from its sources to the cross section is 1.56 km. Górka is of agricultural-settlement character, where agricultural land constitutes 89% and the built up area covers 8.1% with population density of 2.27 person · ha^{-1}. The cognitive objective of the work was determining the kind and degree of anthropopressure on the aquatic environment. For this reason water for the analyses was collected at the hydrometric cross section nine times a day at: 5^{00}, 7^{00}, 9^{00} ,12^{00}, 15^{00}, 17^{00}, 18^{00}, 20^{00} and 22^{00}, from Monday to Saturday. Electrolytic conductivity was measured on site, whereas $N–NH_4^+$, $N–NO_2^-$, $N–NO_3^-$,PO_4^{3-}, K^+, Na^+, Cl^-, SO_4^{2-}, Mn^{2+}, $Fe^{2+/3+}$, total dissolved solids and total soluble solids were determined in the laboratory. Water quality was determined on the basis of component concentrations compared with the concentrations admissible for a given water quality class [Rozporządzenie…1991]. Trends of component concentrations over 24 hours were determined as average for the six day period of investigations. The significance of differences of mean daily values were estimated using t-Student test on the significance level α = 0.05. Basing on the investigations it was observed that the water leaving this catchment revealed considerable concentrations of $N–NO_2^-$ and PO_4^{3-}, and elevated content of $N–NH_4^+$, sporadically also higher values of total suspended solids. The highest concentrations of these elements, except total suspended solids occurred usually in the afternoon and evening, the lowest in the morning. On the last day of the measurements (Saturday) a clear increasing tendency of come component, a mainly biogenic concentration was observed. Therefore, the dynamics of the concentrations to a considerable degree overlapped the rhythm of daily and weekly activity of this catchment inhabitants, where arable lands cover a major part of the area. It evidences a major impact of the factor connected with sewage disposal from residential and /or farm buildings on the outflowing waters. In order to decrease the level of biogens outflowing from the Górka microcatchment, a construction of a local sewage system or household sewage treatment plants has been recommended [B.2.1].

Results of the analyses described above allowed me to corroborate the thesis about a negative effect of urbanised areas on the quality of flowing surface waters. They also point to the fact that not only city buildings negatively affect water quality parameters, but even not so numerous rural buildings with an unregulated water supply and sewage treatment system may have a similar effect.

I was also involved in the **analysis of water self-purification processes in the catchment under breeding pressure.** I investigated a 1524 m long section of a watercourse draining a small Wronowiec agricultural catchment**,** carrying waters to the Wieprzówka river, the left bank tributary to the Skawa river [B.2.12; B3.2]. Quality features of the water outflowing from this catchment were affected by cattle farming concentrated in a large barn, whose buildings were situated in the middle course of the watercourse and adjoined it on a distance of about 270 m. Besides the farm building, also three slurry containers, each with a volume of 500 m^3 were situated in the vicinity. Water samples were collected in 10 measurement points, located in places of assumed pollution and along the 1.0 km reach of the watercourse, below the places of pollution. Hydrolytic conductivity was measured on site and selected biogenic substances: PO_4^{3-}, NH_4^+, NO_2^-, NO_3^- and K^+ were determined in the laboratory using reference methods. The results were presented on hydrochemical profiles and water quality was assessed on the basis of values permissible for individual purity classes [Rozporządzenie… 2004].

The data analysis allowed to establish that the Wronowiec watercourse was strongly polluted and water flowing in it had poor quality – class V at some dates of measurements, due to concentrations of phosphates, ammonium ions and nitrites. Water inflow from the side watercourses, owing to dilution of analysed component concentrations and other self-purification processes contributed to the improvement of water parameters in the main watercourse. Distribution of changes of electrolytic conductivity values and biogenic concentrations allowed to identify two zones – upriver – zone of strong pollution formed mainly due to slurry leak from the cattle farm and fields fertilized with it and the lower zone of gradual water purification [B.2.12; B.3.2].

Conducted investigations allowed me to draw a general conclusion, that despite a commonly shared opinion about intensive water self-purification processes occurring in well aerated mountain streams, also strongly polluted water in a small watercourse with a smooth flow has a natural ability for self-purification.

In the years 1999–2001 I conducted studies on **hydrological and hydrochemical regime in the small uncontrolled agricultural sub-mountain catchments**. Some part of the results which I obtained at that time were used in my doctoral dissertation. However, the results of these investigation I have described in point 5.2, not 5.1, because following their thorough analysis and preparation for publication, I have published them after my PhD defence. The research covered 4 experimental microcatchments located in Wadowice county, Malopolskie province, near Andrychów city. Geographically they are situated in the area of Wilamowice Plateau and Wieliczka Plateau and are a part of the Wieprzówka river catchment – a left bank tributary to the Skawa river. Górka, Barnczak and Wronowiec microcatchments have small areas (0.87, 1.21 and 1.60 km^2) and their widths and lengths are approximate. Włosień catchment area is several fold larger (7.04 km^2), whereas its width does not differ much from the width of the other three objects. The differences in altitude location among the catchments are not big – the difference between Włosień mircocatchment, which is located on average at the altitude of 307.2 m a.s.l. and the highest located Wronowiec microcatchment is only 39.4 m higher. Mean weighted average land slopes range from 4.1% in Włosień to 10.0% in Barnczak. The river network density varies 0.87 to 2.75 km^2, respectively in Barnczak and Wronowiec. Diversification in management and land use in the individual analysed objects proved more important than the site conditions. The character of Włosień microcatchment may be determined as animal breeding and agricultural. At the time of the investigations about 78% of the area was used as agricultural lands, of which 8.5% were used as pastures, where on average 240 cows were grazing. The characteristic feature which distinguishes this object from the other was the highest afforestation rate – 16.2%. Górka was of a settlement-agricultural character, where the built up areas occupied 8.1%. Barnczak was a typical agricultural catchment (crop production), where arable lands and grasslands covered about 95% of the area. Crop and livestock farming was conducted in Wronowiec – a horse breeding farm and cattle and poultry breeding farm operated in the catchment. The cattle farm conducted indoor livestock farming and the slurry was stored in containers located close to the investigated watercourse. After harvest it was taken to the fields, which were mostly (i.e. 55 ha – 34% of the catchment) situated within Wronowiec microcatchment boundaries [B.2.2; B.2.4–B.2.10; B.2.14; B.2.17; B.2.21].

Hydrometric cross-sections with the triangular weirs were made in order to measure the surface water runoff from Górka, Barnczak and Wronowiec catchments and the water stages were read from the staff gauges installed next to them. The flow rating curves were elaborated on the basis of their calibration in a hydrotechnical channel. In Włosień microcatchment, at a regular and cohesive cross section only a staff gauge was installed, whereas the rating curve was developed on the basis of field measurements using current meter. Atmospheric precipitations were measured using Hellman pluviometer on our own two precipitation stations – the first one was located in Wieprz village, because of Włosień, Górka and Barnczak microcatchments close location to one another, the second in the area of Wronowiec microcatchment. Mean daily runoffs were determined in $dm^3 \cdot s^{-1}$ on the basis of rating curves and water stages on the staff gauges and then converted into the heights of the runoff layers and runoff coefficients. They were used to determine the monthly, seasonal and annual layers and runoff coefficients [B.2.5; B.2.14; B.2.21].

It was established on the basis of conducted observations, that the subsequent years of the research period were characterized by a considerable diversification of rainfall – the first year was dry, the second average, whereas the third year was very wet. The average annual rainfall in the hydrological years 1999–2001 was 912 mm at Wieprz precipitation station and was only 52 mm lower than the average rainfall at higher located Wronowiec station. In both cases the precipitations constituted 105% of an average precipitation for a multi-annual period, therefore the investigated period was regarded as standard. The highest average annual runoff layer – 524 mm was noted in Wronowiec microcatchment. It exceeded by 16 and 32% the runoffs registered in Barnczak and Włosień. In Górka this parameter was by 153 mm lower than in Wronowiec and reached the lowest value among the experimental catchments. It should be noticed that Wronowiec is characterized by higher precipitations and the greatest density of water network, which greatly increased the runoff from this microcatchment. On the other hand, Górka has elongated slopes, one watercourse without tributaries and meadows covering relatively flat terrain immediately adjoining the watercourse, which creates conditions favourable for a longer and more intensive evapotranspiration. In the half-year arrangement, the average over the research period winter runoffs (November–April) from all microcatchments were lower than the summer ones (May–October). However, the differences between the average runoff indices for the individual half-year periods ranged from 18 mm in Włosień to 60 mm in Barnczak. At diversified annual precipitation indices and site conditions of the individual microcatchments, also annual runoff coefficients were diversified. On average, 41% of the rainwater drained from Górka microcatchment, 44% from the lowest situated Włosień, 49% from Barnaczak microcatchment and 54% from the highest located Wronowiec. Runoff coefficients in winter periods in all catchments were higher than in summer half-year [B.2.5; B.2.14; B.2.21].

My hydrological research shows that considerable water resources, which flow out of even small agricultural catchments might be utilized to satisfy local household needs or fulfil landscape and ecological functions. For these reasons, actions in the area of “small retention” should be undertaken to limit the useless water runoff also from such small catchments.

Hydrochemical research in these small catchments involved surface and rainwater sampling twice a month. The outflowing waters were taken immediately from the watercourses at hydrometric cross sections, whereas rainwater from the rainwater collectors. 16 water physicochemical features from the group of physical, oxygen, biogenic and salinity indices and metals were determined in the samples. On the basis of the results selected descriptive statistics of the analysed physicochemical features were calculated, such as minimum and maximum values, arithmetic means and correlation coefficient. The empirical data from the research were used also for the water quality assessment [Rozporządzenie…2004]. Using t-Student test, an inter-object assessment of the significance of differences between the analysed indices of surface waters was made and values of mean physicochemical parameters of rainwater and surface water within individual microcatchments. The results of precipitations and runoffs measurements and their concentrations proved the basis to compute the loads of analysed components ($kg \cdot ha^{-1}$), deposited with precipitations or carried away with the runoff [B.2.2; B.2.5–B.2.10; B.2.17; B.2.21].

On the basis of average values of analysed physicochemical features it was stated, that settlement and agricultural management of Górka microcatchment and Wronowiec catchment management for animal breeding and agriculture most strongly affected pollution of the outflowing waters. Considering the studied indices, thirteen assumed values higher than assessed in Włosień and Barnczak microcatchment waters. Moreover, the lowest content of dissolved oxygen in Górka and Wronowiec waters confirm their poorer quality. Mean values of phosphates, ammonium nitrogen and BOD_5 in Górka and Wronowiec microcatchments, and manganese only in Górka, whereas chlorides and sulphates in Górka and Wronowiec microcatchments, were statistically significantly higher than in Barnczak and Włosień. The assessment of water quality [Rozporządzenie… 2004] flowing in Włosień stream revealed, that the concentrations of nitrates and content of total suspended solids classified it to class IV, i.e. to water with unsatisfactory quality. Water running off from Barnczak catchment revealed satisfactory quality (class III), which was affected by elevated values of phosphates, iron, manganese, BOD_5 and total suspended solids. On the other hand, waters in Górka and Wronowiec had poor quality (Class V) due to, respectively: phosphates, nitrites and BOD_5, and phosphates and ammonium ions. Higher values of the analysed physicochemical features were registered in the outflowing water. Only ammonium nitrogen concentrations were higher in rainwater, but only for the runoff from Włosień and Barnczak microcatchments. The analysed physicochemical features of surface waters revealed diversified seasonal variability, which apart from the meteorological factors was also affected by the anthropogenic factors, dominant in the individual catchments. Mean concentrations of nitrates and manganese in the runoff from Włosień catchment were statistically significantly higher in the winter half-year, whereas phosphates and electrolytic conductivity values in the summer half-year. Similarly, in Górka and Barnczak, mean values of Mn^{2+}, $N–NO_3^{-}$, and additionally dissolved oxygen values were significantly higher in the winter months, whereas half-year pH and electrolytic conductivity values in the summer. Moreover, in the summer half-year statistically higher mean concentrations of PO_4^{3-} were noted in the water of settlement and agricultural catchment (Górka), as well total dissolved solids in water of a typically agricultural catchment (Barnczak). In the runoff from Wronowiec, higher values of ammonium ions, phosphates, electrolytic conductivity, total dissolved solids and iron occurred in summer, whereas sulphates in winter. On average higher values of the analysed physicochemical features were registered in the outflowing water. Only ammonium ion concentrations were higher in the rainwater, but only for the runoff from Włosień and Barnczak catchments [B.2.2; B.2.8–B.2.9]. Loads of a majority of runoff components were much higher than supplied by precipitation. A derogation from this rule were lower removals of manganese, ammonium nitrogen and phosphates, except for Górka. Regarding the substances important for the environment and agriculture one should notice considerable amounts of phosphates and ammonium nitrogen taken up from Górka and Wronowiec microcatchments and nitrates from all catchments. Considering the studied components, annual loads of ammonium and nitrate nitrogen and sulphates deposited by precipitations on the area of 1 ha of catchment were considerable and constituted a principal source of the area pollution [B.2.6–B.2.7; B.2.10; B.2.17].

Basing on the conducted hydrochemical research, I have concluded that, the main factors diversifying the experimental microcatchments – use and management, against a similar background of site conditions, had a crucial impact on water quality. Results of the investigations corroborated the thesis assumed in the presented research that the main cause of poor quality of water outflowing from rural areas is unregulated water and sewage management system in settlements and livestock farms, and to a lesser degree an extensive crop production.

One of the main directions of research I conducted after the PhD defence was **initial hydrochemical assessment of conditionings for localization of small retention reservoirs planned in the Malopolskie province.** In result of an agreement concluded between the Department of Land Reclamation and Environmental Development, AUK and the Malopolska Bureau of Land Reclamation and Hydraulic Structures, in the years 2005–2006 I started a research on water quality and functional qualities of water in 6 uncontrolled watercourses, included in the Small Retention Programme of the Malopolskie province [Program… 2004].

Field investigations, laboratory analyses and chamber studies were conducted in 4 catchments located in Tarnów county: the Uniszowski stream catchment [B.2.11], Rygliczanka [B.2.13], Wolnika [B.2.19] and Korzeń [B.2.15] and 2 in Suski county: the Bąbola stream catchment [B.2.18] and the Mostowy Potok catchment [B.2.16]. Field works comprised monthly surface water sampling in the place of planned dams of small retention reservoirs and the measurements of the water temperature, pH, electrolytic conductivity, dissolved oxygen concentrations and the degree of water saturation with oxygen. In the laboratory, reference methods were used to determine the next 13 physicochemical indices: total suspended solids from the physical indices group, BOD_5 – from the oxygen group, biogenic indices (PO_4^{3-},NH_4^+, NO_2^- and NO_3^-), salinity (total dissolved solids, SO_4^{2-}, Cl^-, Ca^{2+} and Mg^{2+}) and metals ($Fe^{2+/3+}$ and Mn^{2+}). Moreover, selected physiographic parameters of the experimental catchments were developed. Water quality was assessed in compliance with the Ministry of the Environment Regulation on the classification for presentation of the state of surface and underground waters, monitoring, interpretation of results and presentation of the state of these waters [Rozporządzenie… 2004]. Water functional qualities were determined by comparing the research results with the limit values obligatory for surface water used for potable water supply to people, for fish life under natural conditions and for bathing [Rozporządzenia… 2002a, 2002b, and 2002d]. Field and desk studies allowed to state a dominant agricultural land use in the catchments of the Rygliczanka, the Korzeń and the Wolninka streams, whereas the catchments of the Uniszowski stream, the Bąbola and the Mostowy Potok have a dense forest cover between 54.5 and 76.0% of the area [B.2.11; B.2.13; B.2.15; B.2.16; B.2.18; B.2.19].

Initial results of the hydrochemical research conducted in the years 2005-2007 revealed not much diversification in water quality among the analysed watercourses [B.2.11; B.2.13; B.2.15;

B.2.16; B.2.18; B.2.19]. Waters flowing from four catchments located in the Tarnów county were classified to quality class III due to raised concentrations of total suspended solids, total iron and manganese. These waters may be used for human consumption following the high performance physical and chemical treatment, appropriate for category A3 waters, because of elevated manganese concentrations. Among the analysed indices, nitrites negatively affect the habitat conditions for the salmonid and cyprinid fish, whereas total suspended solids concentration and the degree of water saturation with oxygen sometimes did not meet the requirements for bathing water. Biogenic indices concentrations, whose excess contributes to water eutrophication in reservoirs were on a low level [B.2.11; B.2.13; B.2.15; B.2.19]. Water flowing in the Bąbola stream had good quality (class II) and after its physical and chemical treatment (category A2) could be supplied to people. During the period of investigations the waters also met the requirements for open-air bathing places and fish habitat, and were not threatened with eutrophication due to biogenic concentrations [B2.18]. Surface waters outflowing from the Mostowy Potok catchment were also qualified to class II, i.e. to good quality waters. The planned small retention reservoir could be also used for recreational purposes, also for bathing. Due to raised nitrite concentrations, water flowing in the Mostowy Potok meets the requirements only for the cyprinid habitat. Because of total iron concentrations the water must be treated using physical and chemical methods appropriate for category A2 waters. The estimation of susceptibility to eutrophication revealed, that the waters undergo seasonal brief periods of eutrophication [B.2.16].

The continuation of this research was co-financed by the Ministry of Science and Higher Education. In the years 2007–2010, further works were conducted as part of development grant No. R 12 001 02 and extended for the next 6 catchments. I published the results in a monothematic scientific publication cycle.

The research presented above has a utilitarian nature, because the results may be used for specification of potential functions of planned water reservoirs in the catchments of the analysed watercourses. To ensure the proper water quality and its functional qualities in a majority of tested streams, activities aimed at reduction of pollution with total suspended solids, nitrites, total iron and manganese should be undertaken in their catchments. They should comprise anti-erosion measures and local changes in the land use.

I carried out **investigations on soil erosion potential in the catchment of planned water reservoirs** in the Korzeń stream catchment, located in Malopolskie province, in a close vicinity to Tarnów city. They aimed at verification the hypothesis about a limited permeability of sub-mountain soils and associated poor ability for interception of rainwater and meltwater, which favours erosion processes and may indirectly negatively affect the proper and long lasting operation of the planned "Skrzyszów" retention reservoir. The thesis was verified on the basis of the results of soil analyses. The research involved making 6 soil pits, evenly distributed and representative for all soil sub-types occurring in the catchment. Samples were collected from each genetic horizon and basic physicochemical properties, permeability and soil water potential were determined in them. The empirical data obtained from the laboratory analyses were used to calculate the values of filtration coefficient corrected to 10°C ($cm \cdot d^{-1}$), and useful retention and static leachability (% vol. and mm) [B.2.24].

Analysis of the research results revealed that heavy soil lessivés and leached brown soils occur in the catchment, but also lighter deluvial and acid brown soils. They are composed prevailingly of silt and silt-clay deposits, more rarely of sandy silts and loams. Values of filtration coefficients range from zero to several or more than a dozen, and very rarely several dozen cm daily. These soils have considerable retentive potential (from 173 to 347 mm), which is not fully utilised because of their low permeability thus limiting infiltration of rainwater and meltwater [B.2.24].

Basing on the data analysis I established, that due to the soil physicochemical properties, surface runoffs occur in the Korzeń catchment, which at considerable land slopes and dominant agricultural management of the area exacerbates erosion processes and in future may contribute to silting up the planned "Skrzyszów" water reservoir. In order to reduce the surface runoffs and protect the future reservoir, the soil permeability in the Korzeń stream catchment should be increased through appropriate management and land use, by means of land reclamation measures, and also construction of a preliminary reservoir should be considered.

Regarding the aquatic environment protection, I concerned myself with the problems of **innovative method of management of rainwater** runoff from hard surfaced roads, parking lots or pavements of the Logistics Centre situated in Modlniczka on the outskirts of Krakow [B.5.9].

The Centre area of 31.5 ha, on which currently 9 large-size storage facilities are situated, is located in the Wedonka stream catchment and within the water intake zone for Krakow on the Rudawa river. The vehicle transport associated with this enterprise poses a potential hazard to both ground and surface waters. For this reason, the investor decided to apply an unusual solution aimed at getting rid of rainwater from the Centre area. It involves collecting water in a local container and then sprinkling it on the area of several storage facilities roofs and evaporating. Prior to my research outset, jointly with my colleagues from the Department of Land Reclamation and Environmental Protection, I designed a special experimental station composed of a model of storage facility roof in 1:1 scale, equipped with sprinklers. The whole station was fully metered, which provided the full control of water cycle and allowed to determine the evaporation from the difference between the inflow and outflow during the roof surface sprinkling. A modern meteorological station was installed close to the experimental roof [B.5.9]. The tests were conducted from August to October 2010 and from April to October 2011 and 2012. They aimed at determining the dynamics of water evaporation from the sprinkled roof of the industrial building and establishing the dependence between the quantity of evaporating water and meteorological factors. The volumes of water supplied to the roof and drained from it, as well as a number of meteorological elements were measured continuously. These parameters were recorded in the recorder memory at the 30-minute intervals. Moreover, the surface moistened by 6 sprinklers on the experimental roof was measured systematically once a week. The differences between the volume of water supplied and drained from the roof divided by mean values from the two neighbouring dates of moistened roof surfaces measurements, enable to determine the water evaporation layer in millimetres. The recorded and calculated parameters provided the basis to establish their hourly sums or mean values. Measured precipitations and recorded times of their occurrence were used to determine the number of rainless hours, of which data were used for the computations [B.5.9].

It was established on the basis of results analysis, that in each year of the studies, calculated evaporation sums were markedly higher during the day than at night. Mean over the years 2010–2012 sum of the water evaporated from the roof surface was the highest in the summer season – 574 mm, in which daytime evaporation constituted 87% (499 mm). On average for the period of investigations, 5.9 dm^3 of water evaporated daily from 1 m^2 of moistened roof surface. Evaporation calculated for p = 0.10 corresponding to the statistical repeatability period once in 10 days, i.e. occurring about 41 times (40.7) during the period of research (407 days) was 8.8 mm and with 20 times (p = 0.05) repeatability 9.6 mm, whereas statistically occurring once in 100 days (p = 0.01), i.e. four times during the research, reached the value of 11.2 mm. Average for the experiment period evaporation in night and daytime hours was respectively 0.11 and 0.35 $dm^3 \cdot m^{-2} \cdot h^{-1}$ [B.5.9].

The obtained results enabled a selection of appropriate roof surfaces and optimal method of their sprinkling and dimensioning the elements of hydraulic installation for the system ensuring management of rainwater running off the Centre paved surfaces. Moreover, established values of water evaporation for the sprinkled area unit may be used to determine the roof areas necessary for the evaporation of desired amount of water, on condition that the identical construction and material solutions are applied for the roofs and their sprinkling method.

Another direction of research connected with one of my scientific specialisations – agricultural land reclamation was the assessment of **the impact of selected agricultural land reclamation measures on physicochemical soil properties.** Increasing level of mechanisation accompanying agricultural production causes, that machine moving on the field surface causes the topsoil and subsoil compaction contributing to the worsening of soil physical parameters. Also, in result of cultivation measures of soil to the same depth an unfavourable phenomenon called soil thickening occurs, which accumulating in time may lead to unfavourable changes of its physical-water properties. It affects reduced use of potential retentive capacities, decrease in soil productivity and increase in surface runoffs. One of the methods to improve soil parameters is application of agricultural land reclamation measures, so the aim of research in this area was determining the impact of deep soil loosening on the change of physical water properties of brown earths and typical lessive soils.

The research was conducted in 2012–2013 on arable lands located in Wojnowice village (Racibórz county). The soils in this area belong to class III and to good wheat complex due to their agricultural usability. However, these are heavy soils and susceptible to mechanical thickening, which negatively affect air and water relations and decreases their infiltration abilities. The field work comprised making two soil pits (on the field with deep soil loosening and without it), which were described in detail. Soil samples of undisturbed and disturbed structure were collected from individual genetic horizons. Soil permeability tests were conducted at each soil pit. The field tests and laboratory analyses provided information about the soil texture, its moisture content, humus content, characteristic densities and soil porosity [B.2.31; B.2.34].

Even the preliminary analysis of the research results allowed for the statement that applied deep soil loosening using the deep loosener influenced diminishing of volumetric density and increase in soil total porosity and permeability. The air and water relations improved, too; the proportion of gaseous phase increased, whereas the liquid phase decreased [B.2.31; B.2.34].

On the basis of conducted research results I demonstrated, than even 20 months after application of agricultural land reclamation measures, their beneficial impact on physical water soil parameters was visible, which in consequence should increase soil productivity, but may also lead to alleviating the drought and flood results.

I participated, as a leader of hydrochemical section, in research focused on **environmental and hydrochemical conditionings for revitalisation of Chechło water reservoir,** which was conducted under the framework of a partner agreement between the Faculty of Environmental Engineering and Land Surveying and the city of Trzebinia. The analysed reservoir was constructed in 1944–45 mainly for water retention for industrial plants and fire protection needs. Moreover, it serves water outflow alimentation in the Chechło river channel, reduces flood results in the valley below the dam and fulfils recreational functions. It is fed by two main tributaries, i.e. the Chechło river and the Młoszówki stream. The aim of the natural and hydrochemical research carried out in 2012–2013 was to obtain as much as possible reliable data and information which could provide a basis for developing a revitalisation project and multifunctional use of Chechło reservoir. The results were published in 2014 as a monograph by many authors [B.2.33] containing the characteristics of the reservoir and its surroundings. The factor basic for the reservoir usable function, but also for the proper functioning of aquatic and water-dependent ecosystems, is proper water quality, which was assessed on the basis of physicochemical and biological parameters. The authors presented also the level or the soil and plant pollution with heavy metals. Vegetation in the reservoir and its surroundings was characterised and the importance of the reservoir was assessed regarding bird habitats.

The investigations revealed, that the species diversity of breeding avifauna of Chechło reservoir is comparatively small, as only 19 bird species were identified there. Aquatic and rush vegetation of the reservoir does not represent any natural values, because only common species occur, there are no rare or valuable protected species. However, a floristic diversity is considerable and a typical zonal vegetation pattern has developed in some parts of the reservoir. Semi-natural meadow communities surrounding the reservoir are mostly characterised by a poor species composition and little typical formation caused mainly by a lack or improper land use. Chromium and nickel in terms of toxicity proved natural in the analysed soils, whereas on some test sites, the soil was medium polluted with lead and zinc, and strongly polluted with cadmium. Cadmium and zinc concentrations in plants, exceeding the values regarded as forage usability limit, were found in some test points. Therefore, plant cultivation for forage or consumption is not recommended in the reservoir vicinity. Catchments of the Chechło river and the Młoszówka stream are characterised by considerable retentive potential, which is in the first place connected with their use and topography, i.e. dominance of forests and slight land slopes. A considerable proportion of forests in the catchment on one hand contributes to lower the maximum runoff, however on the other may affect increase in water deficits in case of long rainless periods. Hydrological modelling revealed that a faster catchment response to precipitation is possible in the Młoszówka catchment than in the Chechło river catchment . It is connected with its smaller area, much greater land slopes and with a lower share of the land of a considerable retention capacity (forests and grass ecosystems). Chemical state is good, whereas ecological state of the reservoir and the Chechło river, assessed on the basis of biological, physicochemical indices and substances particularly harmful for the aquatic environment is moderate (class III) - the water is permanently polluted with organic substances of natural origin, whose source is the soil and plant environment of Dulowski Forest. On the other hand, waters inflowing to the reservoir by the Młoszówka stream have good ecological and chemical state. Due to BOD_5 values, concentrations of total phosphorus and nitrite nitrogen, habitat conditions unfavourable for the cyprinid and salmonid fish occur in the investigated water. Depending on the index used and trophicity assessment method, Chechło reservoir is classified to eutrophic or even hypertrophic bodies of water [B.2.33].

Despite of the assessed relatively low natural value of Chechło reservoir, it plays an important role in increasing biodiversity of the Trzebinia district area, which is strongly degraded by industry. Therefore, future plans of the reservoir management should focus more on the natural environment protection. The environmental function should dominate, particularly in the south-eastern part of the reservoir. A revitalisation of the area is recommended, as it would make possible increasing the number of animal species and their number. A change of the habitat conditions through modification of the existing or forming new vegetation patches and forming of islands would contribute to improvement of habitat conditions for birds.

I was also involved in **studies on water and nutrient losses in the open drip irrigation system in large area greenhouses** at rose cultivation on the peat substrate. Water runoffs were measured using calibration vessel at the time when 2 or 3 cycles of irrigation with various spray doses were applied. Laboratory determinations, conducted on averaged samples of media and leachates by means of reference methods, involved concentrations of 8 nutrients: $N–NH_4^+$, $N–NO_2$, $N–NO_3^–$, $PO_4^{3–}$, K^+, $SO_4^{2–}$, Ca^{2+} and Mg^{2+}. On the basis of measured volumes of leachates and concentrations of nutrients in them and basing on the volumes and concentrations of components in the nutrient solution supplied to plants, respectively loads supplied and removed from the system were computed. The percent value of nutrient loses was established from their quotient [B.2.35].

Analysis of the results revealed a considerable diversification in the volumes of leachate run-off depending on the quantity of irrigation spray dose and for the number of cycles realized during the day. The investigations demonstrated a potential decrease in water loses in the irrigation system, which depending on the calculation variant under the experiment conditions were between 21.6 and 99.8%. An increase in concentrations of : Mg^{2+}, SO_4^{2-}, K^+, $N–NO_2^-$ was found in comparison with the nutrient solution supplied to plants, i.e. so called phenomenon of leachate concentration was observed. Because of this phenomenon, on average the greatest, i.e. 70–90% quantitative loses were observed for the same 4 nutrients. However, it should be emphasized that nutrient loses occurred at each testing period and to various degree concerned all analysed components [B.2.35].

In the light of obtained results I established, that seeking the methods of rational water and fertilizer management in closed drip irrigation systems seems fully justified due to economic and environmental reasons.

I was also researching **quality changes of water flowing along the length of selected Malopolska rivers,** i.e. the Prądnik-Białucha river [B.2.28]. the Poprad [B.2.36] and the Uszwica [B.2.41]. The investigations aimed at determining the changes of water quality and its functional qualities, as well as delineation the water pollution and self-purification zones along the lengths of rivers , whose catchments are located in the upper Vistula basin.

The Prądnik-Białucha river, whose catchment is situated in the vicinity of Krakow on the Krakow-Częstochowa Upland, flows through typically agricultural areas, legally protected, with dispersed rural settlements, suburban and urban built up areas. Hydrochemical research conducted in 15 measurement points involved determining 23 physicochemical indices by means of referential methods. On the basis of the data analysis it was established that in the upper reach of the river, spring waters were enriched in or depleted of minerals. Self-purification processes improving water quality occurred along the middle reach, in the area of the Ojców National Park and its buffer zone, which was connected with a lower anthropopressure and greater afforestation rate of this area. In the lower reach of the river, compact suburban and urban development caused intensive water pollution. Due to high concentrations of nitrates, water flowing along the whole river length was threatened with eutrophication and had ecological status below good. The analysed water was suitable for consumption, but along various river reaches needed the treatment processes adjusted to the requirements of A1, A2 or A3 category. Except for a short headwater reach of the river, high nitrite concentrations did not provide convenient natural conditions for the salmonid or cyprinid fish habitats [B.2.28].

The Poprad river, 167 km long and with the catchment area of 2077.3 km^2, in its upper course flows for over 100 km through the territory of Slovakia and along the length of 31.1 km is a transboundary river, whereas the lower course, about 31.0 km long is located on the territory of Poland. Regarding the abiotic factors, it is a medium upland-eastern, type 15 river, a right-hand tributary to the Dunajec. The research was conducted for five years in three measurement points: 1. located in Leluchów on the Polish-Slovak border at 62.1 km of the river course, 2. in Piwniczna-Zdrój – in 23,9 km, 3. in Stary Sącz – 2.9 km before the Poprad outlet into the Dunajec. 21 physicochemical indices and 2 microbiological indicators were determined in the water samples, on the basis of which the changes of ecological state and functional qualities of the water along the analysed Poprad river reach were assessed. Moreover, statistical differences between the values of individual indices determined in various measurement points were estimated by means of non-parametric U Mann-Whitney test. On the basis of conducted analyses it was stated, that regarding the physicochemical indices, ecological state along the whole studied river reach was good (class III) – in points 1 and 3 it was determined by mean concentrations of total suspended solids, whereas in point 2 the values of COD-Mn. Frequent high concentrations of total suspended solids did not meet the requirements for surface waters used for water supplies to people , and the values of some quality indices proved not very favourable habitat conditions for development of the salmonid and cyprinid fish. Statistical analysis revealed significant increase in nitrite nitrogen, total phosphorus, phosphates and COD-Mn along the reach between points 1 and 3, whereas pH, the contents and water saturation with oxygen diminished. Moreover, it was found, that in the point located in Piwniczna-Zdrój the coli bacteria and faecal coli bacteria numbers were significantly lower than in the point on the Polish-Slovak border and in the estuarine point [B.2.36].

The Uszwica river catchment is located in the central part of the Malopolskie province, in the area of Brzesko and Bochnia counties. The river is 61.2 km long and its catchment covers the area of 322.5 km^2, which due to its management has a forestry-agricultural character with considerable proportion of compact development (Brzesko city) and dispersed housing. Two-year hydrochemical research was conducted in two measurement points – one located in the estuarine part (point 1) and the second located about 7.5 km below Brzesko city (pint 2). The values of 18 water quality indices determined every month were subjected to comparative and statistical analyses – basic descriptive statistics were computed for each index in both points and their seasonal variability was assessed, ecological state and water functional qualities were established, whereas the statistical significance of difference between the values of individual indices noted in various measurement points was estimated by mean of U Mann-Whitney test. Analysis of the results revealed, that along the whole studied Uszwica river reach, water did not meet the requirements for the salmonid and cyprinid fish, however much better conditions were in the estuarine river reach. The water under settlement pressure (point 2) was significantly less saturated with oxygen and contained greater amounts of total suspended solids, organic and biogenic substances in comparison with the river reach flowing through extensively utilised agricultural lands. For these reasons, the water from the central Uszwica river reach was eutrophic and had ecological potential below good. The seasonal cyclicity of changes of some biogenic indices, which occurs in clean waters, was also disturbed. On the other hand, in result of intensive self-purification processes the conditions in the river estuarine part were close to normal, i.e. seasonality was maintained, water was not threatened with eutrophication and had good ecological potential [B.2.41].

On the basis of the results of analyses carried out in the catchments of three rivers located in the Upper Vistula basin, I demonstrated that despite numerous pro-ecological measures limiting water pollution in Poland, there are still problems with the realization of river environmental objectives stated in the Framework Water Directive.

Beside the above described main directions of research I conducted after a doctoral degree, I was also involved in a number of other projects, which were mainly focused on mechanisms shaping water quality, mainly in surface waters.

6. INDICATION OF SCIENTIFIC ACHIEVEMENT FOLLOWING article 16 par. 2 of Law on Academic Degrees and Title and Degrees and Title in Arts of 14 March 2003 (Journal of Laws no. 65, item. 595 as amended.)

6.1. Title of scientific achievement

Monothematic publication cycle

"*The impact of selected anthropogenic factors on surface water quality shaping in upland and mountain catchments*"

6.2. List of papers documenting scientific achievement

B.1.1. Kanownik W., Kowalik T., **Bogdał A.**, Ostrowski K., Rajda W. 2012. *Quality and usable values of waters flowing away from catchments of planned small retention reservoirs in the region of Cracow*. Monograph (in English). Ed. UR Krakow, pp. 110. ISBN 978–83–60633–63–2 (my contribution – **15%**) [**MNiSW – 25 points**].

Kanownik W., Kowalik T., **Bogdał A.**, Ostrowski K., Rajda W. 2011. *Jakość i walory użytkowe wód odpływających ze zlewni zbiorników małej retencji planowanych w rejonie Krakowa*. Monograph (in Polish). Ed. UR Krakow, pp. 110. 110, ISBN 978–83–60633–58–8.

The role and contribution of the habilitation candidate: involvement in developing the concept and realisation of field works and laboratory analyses, developing physiographic characteristics of the studied catchments, data analysis, developing conclusions and text edition.

B.1.2. **Bogdał A.**, Kanownik W., Kowalik T., Ostrowski K., Rajda W. 2014. *Jakość i walory użytkowe wód odpływających ze zlewni wybranych zbiorników małej retencji planowanych na Pogórzu Ciężkowickim* (*The quality and functional values of runoff waters from catchments of selected small retention reservoirs planned on the Ciężkowice Plateau).* Monograph (in Polish). Ed. UR Krakow, pp. 136. ISBN 978–83–64758–10–2 (my contribution – **50%**) [**MNiSW – 20 points**].

The role and contribution of the habilitation candidate: involvement in developing the concept and realisation of field works and laboratory analyses, developing physiographic characteristics of the studied catchments, data analysis, the author of *Results* chapter and co-author of conclusions and text edition.

B.1.3. Kowalik T., **Bogdał A.**, Kanownik W., Ostrowski K., Rajda W. 2010. *Quality and functional values of waters flowing away from catchments of planned small storage reservoirs in the Beskid Makowski and Żywiecki Mts*. Monografia. Monograph (in English). Ed. UR Krakow, pp. 94. ISBN 978–83–60633–53–3 (my contribution – **15%**) [**MNiSW –**

25 points].

Kowalik T., **Bogdał A.**, Kanownik W., Ostrowski K., Rajda W. 2010. *Jakość i walory użytkowe wód odpływających ze zlewni planowanych zbiorników małej retencji w Beskidzie Makowskim i Żywieckim.* Monograph (in Polish). Ed. UR Krakow, pp. 94. ISBN 978–83–60633–52–6.

The role and participation of the habilitation candidate: involvement in developing the concept and realisation of field works and laboratory analyses, developing physiographic characteristics of the studied catchments, data analysis, co-author of conclusions and text edition.

B.1.4. Kowalik T., Kanownik W., **Bogdał A.**, Policht-Latawiec A. 2014. *Wpływ zmian użytkowania zlewni wyżynnej na kształtowanie jakości wody powierzchniowej* (*Effect of change of small upland catchment use on surface water quality course*). Annual Set The Environment Protection – Rocznik Ochrony Środowiska 16, 223–238 (in Polish) (my contribution – **30%**) [**MNiSW – 15 points, IF = 0,442**].

The role and participation of the habilitation candidate: involvement in developing the concept and realisation of field works and laboratory analyses, developing physiographic characteristics of the studied catchments, data analysis, co-author of conclusions and text edition.

B.1.5. **Bogdał A.** 2011. *Wpływ zabudowy hydrotechnicznej rzeki na zawartość i nasycenie wody tlenem rozpuszczonym* (*The impact of river hydraulic structures on the content and water saturation with dissolved oxygen*). Gaz, Woda i Tech. Sanit. 10, 349–351 (in Polish) (my contribution – **100%**) [**MNiSW – 9 points**].

The role and contribution of the habilitation candidate: developing the concept and realisation of field works and laboratory analyses, the data analysis, preparation of tables and figures the text edition and developing final conclusions.

B.1.6. Kowalik T., **Bogdał A.**, Borek Ł., Kogut A. 2015. *The effect of treated sewage outflow from a modernized sewage treatment plant on water quality on the Breń river*. Journal of Ecological Engineering 16 (4), 96–102 (in English) (my contribution – **45%**) [**MNiSW – 12 points**].

The role and contribution of the habilitation candidate: participated in developing the concept and realisation of field works and laboratory analyses, the data analysis, preparation of tables and figures the text edition and developing final conclusions.

B.1.7. Policht-Latawiec A., **Bogdał A.**, Pudło M. 2013. *Effect of small water reservoir on quality and usable values of surface waters*. Teka Komisji Ochrony i Kształtowania Środowiska Przyrodniczego PAN, 10, 334–346 (in English) (my contribution – **45%**) [**MNiSW – 4 points**].

The role and contribution of the habilitation candidate: participated in developing the concept and realisation of field works and laboratory analyses, the data analysis, preparation of tables and figures the text edition and developing final conclusions.

B.1.8. **Bogdał A.**, Kowalik T., Witoszek K. 2015. *Wpływ Zbiornika Goczałkowickiego na zmiany jakości wód w rzece Wiśle* (*Effect of the Goczałkowice Reservoir on the changes of water quality in the Vistula river*). Inżynieria Ekologiczna 45, 124–134 (in Polish) (my contribution – **60%**) [**MNiSW – 9 points**].

The role and contribution of the habilitation candidate: participated in developing the concept and realisation of field works and laboratory analyses, the data analysis, preparation of tables and figures the text edition and developing final conclusions.

Total number of points for original creative papers included in the above mentioned monothematic publication cycle acc. to MNISW is 119, of which 44 account for my own contribution. Annex No. 7 contains the author contribution forms of all co-authors of the publications constituting the monothematic publication cycle.

Introduction

It is a common knowledge, that water is priceless good and heritage indispensable for life and despite technological progress in all spheres of life, no substitute has been discovered so far [Cybulska 2012]. Therefore, its quality status must be protected and its wastage avoided [Duer 2005]. Rational management of water resources determines the possibilities of multifunctional and sustainable development of cities and rural areas, leading to the improvement of civilizational and living conditions of local communities [Mosiej and Somorowski 2001].

Civilisation, technological and economic progress, but also intensive urbanization and development of rural settlements, contribute to increased water consumption in Poland [Chucki and Staszewski 2012]. Lack of transit rivers, dominance of sandy soils and small percentage of water collected in natural or artificial reservoirs cause, that water resources in our country originate mainly from atmospheric precipitations, which depending on the geographical region are on average between 450 and over 1000 mm. For these reasons, they are greatly variable, both regarding their spatial and time distribution [Małecki and Gołębiak 2012], which in many places leads to either water excess or deficiency.

In comparison with other European countries, Poland has very small water resources, which gives it 22nd position in Europe. The amount of water per one inhabitant of Poland is acc. to IMGW 1580 m^3 per year, whereas there is about 4900 m^3 water per one European [Małecki and Gołebiak 2012]. Having such small water resources, we have to manage them rationally and consciously, i.e. respecting all natural laws. Rational management must involve both its quantitative state and qualitative status, which requires thorough identification and eliminating any sources of surface water pollution.

With a view to the quantitative aspects, we should take care that at the time of water excess, it would not flow uselessly from the catchment area. One of the methods to solve this problem are measures known as small retention. Their task is to use technical, agrotechnical and planning-organisational tools to delay the water runoff and therefore increase its availability for various purposes and different users [Mioduszewski 2006, Radecki-Pawlik and Kapusta 2006, Mrozik and Przybyła 2013].

Long drought period, floods and local inundations caused by a violent course of atmospheric phenomena are natural disasters and cause considerable economic losses. Recent years showed, that these phenomena may occur almost everywhere and with various intensity. Guided by rational premises, we have to implement programmes of water management through reducing the causes and preventing the outcomes of extreme hydrological phenomena. Construction of large and small so called “small retention” reservoirs may serve these purposes [Mioduszewski 2003, Ostrowski and Bogdał 2006, Liberacki and Stachowski 2008]. However, the purposefulness of water storage in retention reservoirs is determined by the substances it contains, whose concentrations depend, among others on the method of management and use of the catchment [Mosiej and Somorowski 2001, Rajda 2005, Rajda and Kanownik 2005, Suchowolec and Górniak 2006, Koc and Skoniec-zyk 2007, Ostrowski and Bogdał 2007, Ostrowski et al. 2011, Wiatkowski and Rosik-Dulewska 2011, Bedla and Misztal 20014]. Therefore, already at the designing stage one should precisely identify not only the quantitative but also qualitative state of the stored water. Unsatisfactory quality may limit ecological and economic water utilization and causes difficulties in the reservoir exploitation, where oxygen deficit and eutrophication processes may occur at the excess of biogenic substances causing development of vegetation [Murat-Błażejewska et al. 2003, Wiatkowski 2006, Wiatkowski et al. 2010, 2012, Bogdał and Ostrowski 2008, Przybyła et al. 2014b]. Good quality of water in the reservoirs may be maintained owing to regulated water supply and sewage treatment systems, realization of agro-environmental programmes but also due to education of the communities inhabiting a given river catchment [Kornijów 2011].

Humans by their activities, usually negatively influence the environment, including aquatic environment. Civilization progress leads to the changes of terrain relief and soil cover, land reclamation or inundation are conducted causing degradation of soils, forests, natural ecosystems and surface waters. All the changes which are the result of indirect or direct human impact on the environment are called anthropogenic changes, whereas the activities causing them are anthropogenic factors.

Chemical components content in surface waters depends on the natural and anthropogenic factors. The natural substances, whose sources are rocks, non-tilled soils, humus substances, organic matter decomposition and clean atmospheric precipitations make up the natural water quality. Inflowing anthropogenic substances usually cause water pollution and in this way change its original, natural composition [Rajda and Natkaniec 2001, Bogdał and Ostrowski 2008, Bulut et al. 2010]. According to the way of their supply to water, they may be divided into area, point and linear pollution [Kiryluk at al. 2014].

Pollution denotes unfavourable changes of physical, chemical or biological properties of surface waters. In this meaning it involves the amounts of substances supplied to the waters, which exceed the safe, natural or possible to assimilate values, i.e. they influence a decrease in functional values and water self-purification [Rajda and Kanownik 2005, Durkowski et al. 2006, Melcer and Olejnik 2006, Niczyporuk and Wiater 2006, Olszewska and Krzemińska 2008, Skorbiłowicz 2007, Liu et al. 2010, Al-Shami et al. 2011, Bogdał et al. 2012a, Policht-Latawiec and Kapica 2013]. In rural areas, anthropopressure on surface water quality is associated with crop and livestock production. Added to this is pollution from urbanised areas, from untreated or inadequately treated sewage discharge, from washing out of various substances from private properties, communication routes or landfill sites [Twardy and Jaguś 2001, Jekatierynczuk-Rudczyk et al. 2006, Rossa and Sikorski 2006, Bakarat et al. 2013]. It may be the result of pollutant emission to the atmosphere which returns to the catchment surface [Durkowski and Korybut-Woroniecki 2009, Bogdał et al. 2012b].

The land use and management greatly impact the quality of surface waters. Forest catchments, where no aggressive land use forms occur, or considerably afforested catchments with low proportion of agricultural and/or settlement areas have been treated currently as the objects with close to natural environmental conditions. They are the usual reference points for the runoff waters from catchments under stronger anthropopressure resulting, for example from variously intensive agricultural use or caused by the proportion of settlement areas, or even from urbanised catchments [Liberacki 2004, Jekatierynczuk-Rudczyk et al. 2006, Rajda and Natkaniec 2006].

In rural areas the quality of surface waters outflowing from agricultural areas or agricultural and settlement areas is usually a resultant of many factors. Their impact on shaping the physico-chemical composition and functional qualities of waters is different and variable in time [Pulikowski 2004, Monaghan et al. 2007, Ostrowski and Bogdał 2007, Pulikowski et al. 2008, Misztal and Kuczera 2010, Orzepowski 2014]. The most unfavourable effect of agriculture on surface water quality manifests itself through intensified inflow of phosphorus and nitrogen compounds, i.e. so called biogenic substances, which together with potassium constitute a basic set of fertilizer components supplied to the soil owing to cultivation techniques application. Fertilizers used in excess are only partly utilized by plants and the rest is washed out by precipitation waters to surface waters where they cause lush algal bloom and a number of other negative phenomena known as eutrophication [Koc 1998, Podedworna and Marciniewicz 2004, Koc and Skonieczny 2007, Macrae et al. 2007, Solovey 2008, Żmudaandi Szewrański 2008, Ilnicki 2014, Miatkowski and Smarzyńska 2014, Krasowska and Banaszuk 2015]. In order to improve the quality of water subjected to pressure from the area sources, one should observe the principles of good agricultural practice, connected with fertilizer management and anti-erosion measures [Żmuda et al. 2001]. Moreover, in order to limit the direct biogenic migration from arable fields to surface waters, afforested or/and turf riparian zones, so called biogeochemical barriers, should be set up along watercourses and water bodies [Murat-Błażejewska i in. 2003, Suchowolec i Górniak 2006, Wiatkowski i in. 2010, Przybyła i in. 2011].

Undoubtedly, the proper land use has a positive impact on the quality of surface water outflowing from agricultural catchments with greatly diverse land forms [Theodoropoulos and Iliopoulou-Georgudaki 2010], including transformation of arable lands into permanent grasslands. The fact was corroborated by the research of Kopacz et al. [2007], who presented the relationship between the load of agricultural nitrogen supplied to the catchment area and changes in the land use in the Upper Vistula basin. In result of a decrease in this element load caused by shrinking agricultural land area, mainly arable lands and change of pastures into permanent meadows, better protecting the soil against erosion, the anthropogenic pressure on the river catchments diminished [Kopacz et al. 2007]. In many mountain and upland catchments of southern Poland agricultural land use was almost totally abandoned, which led to self-turfing of arable lands and self-overgrowing of grasslands. In result of these changes, the load of agricultural area pollutants, mainly nitrogen compounds, diminished, which translated itself into improved water quality. However, in some catchments increased water concentrations of phosphates were observed in result of increased share of built-up areas [Kopacz, Twardy 2006]. Similar tendencies for lowering the anthropopressure due to arable lands transformation to forest and permanently turfed areas was observed in the San and Wiatr rivers catchments, but because of a meagre increase in urbanised areas, water quality improved, also owing to a decline in phosphorus concentrations [Kuźniar et al. 2008].

Urbanised areas and point source pollution connected with them have a considerable impact on worsening surface water quality, because they discharge the concentrated pollutants to watercourses and other water bodies [Koc and Skonieczyk 2007, Kanownik and Rajda 2009, Misztal and Kuczera 2008, Lai et al. 2013, Hutchins 2012, Mouri et al. 2012]. These comprise mainly municipal and industrial sewage discharged directly into waters or drained from sewage treatment plants, which not always meets the standards and does not eliminate all pollutants [Durkowski and Wesołowski 2008, Kanownik and Rajda 2011, Kiedrzyńska et al. 2012].

In case of treated sewage discharge to surface waters it is important that the pollutant load should not limit water self-purification process [Juszkiewicz et al. 2006]. Therefore, the appropriate oxygen conditions, indispensable for the organisms participating in water self-purification process, must be provided along the whole length of the river course below the treated sewage discharge. Unfortunately, a majority of models applied for the description of treated sewage mixing with receiving waters assume their total mixing in the place of discharge or close to it. However, it happens very rarely, because the speed of this process depends on the pollutant load and amount and velocity of flowing water, but also on the receiving water parameters [Kanownik and Rajda 2011].

Research conducted by Kiedrzyńska et al. [2012] demonstrated a negative effect of sewage treatment plants on the Pilica river water quality. However, it was revealed, that a more serious problem of water pollution occurred in case of small objects in which it was difficult to reach the proper chemical component balance in the treated sewage. The problem is less serious in large treatment plants owing to more advanced treatment technologies, however loads of biogenic substances inflowing to the receiving water are usually very big. The thesis has been corroborated by the research conducted in the San river catchment where quality indices values were determined in the treated sewage discharged from a large treatment plant and in the river water – above and below the discharge. The investigations revealed, that even in case of the discharge of sewage meeting the standards stated in the regulation and water permit, concentrations of a majority of analysed indices were increasing in the San river water below the discharge, but they were statistically insignificant [Policht–Latawiec et al. 2013]. The research carried out by Królak et al. [2011] focused on a similar subject. It concerned the impact of mechanical-biological sewage treatment plant on the quality state of the Zielawa and the Lutnia watercourse water. On the basis of these investigations it was stated, that treated sewage still contained big amounts of nitrate and ammonium ions, had high electrolytic conductivity and therefore it worsened water quality state in the analysed watercourses. Similar conclusions arising from the research of other authors [Juszkiewicz et al. 2006, Kanownik and Rajda 2008, 2011, Skorbiłowicz et al. 2003], who conducted the assessment of the impact of treated sewage discharge on water quality in the Rudawa river, the Sudół Dominikański and the Jaszczurówka streams, and the Narew river.

Mosiej et al. [2007] assessed the effect of subsequent stages of start-up of a group sewage treatment plant for Łódź city agglomeration on the water quality in the Narew river. The investigations demonstrated, that after commissioning of subsequent biological treatment lines the pollutant loads discharged from it decreased, which did not equally translate itself into decreasing of their concentrations along the 25 km long reach of the receiving water. It evidences the disappearing self-purification potential of the river and potential intensification of the processes of chemical substances release from the bottom deposits, which led to secondary river pollution. It shows, that construction of high-performance sewage treatment plant does not ensure any radical improvement of the receiving water quality.

An important factor affecting improvement of surface water quality is self-purification process [Kwapuliński et al. 2008, Grzywna 2014]. Its intensity depends on the kind and degree of pollution, conditions of the aquatic environment, including the temperature, oxygen concentrations and water oxygenation, presence of aquatic vegetation, micro- and macro-organisms, velocity and volume of discharge [Ostrowski et al. 2008] and hydrotechnical structures [Krzemińska et al. 2006]. River damming and construction of retention reservoir significantly affect physical, chemical and biological processes occurring in water. In result of damming, water table area and depth increase, the flow time lengthens and the velocity of flowing water decreases considerably. In rivers, with numerous hydrotechnical structures, i.e. weirs, sluice gates and artificial retention reservoirs, self-purification processes occur differently than in free flowing watercourses [Kanownik et al. 2011, Przybyła et al. 2015].

Dissolved oxygen is indispensable for aquatic plants and animals, it is also very important for all chemical and biochemical processes in waters. It originates in the first place from diffusion from the atmospheric air and from the photosynthesis processes. If the adequate amount of oxygen is present in water, the aerobic processes dominate, which from the water quality point of view are more advantageous, since they trigger the processes of biochemical pollutant breakdown [Chełmicki 2001]. Various opinions about the impact of river hydraulic structures on the quality of flowing water may be encountered in literature. On one hand, worsening of oxygen conditions may occur in result of decreasing water flow velocity before the damming and regulating structures; on the other in result of water flow through the structures, laminar flow changes into turbulent flow, which consequently favours water saturation with oxygen and intensifies water self-purification processes [Dojlido 1995, Chełmicki 2001, Krzemińska et al. 2006, Hachoł and Krzemińska 2008, Brzeziński and Bonisławska 2010].

Studies on the impact of a retention reservoir on a lake protection against phosphorus run-offs from an agricultural catchment were conducted in the lower course of the Sząbruk river. A decrease in total phosphorus concentration occurred in result of water flow through the reservoir. It was found, that the reservoir functions as a barrier intercepting phosphorus compounds runoff from the catchment, however its role reducing pollution was limited to the vegetative period [Koc et al.2008]. Kupientyn reservoir located on the strongly polluted Cetynia river did not reduce biogenic substances concentrations sufficiently and therefore did not properly protect the main "Niewiadoma" reservoir against eutrophication. A low, only several percent reduction of phosphate and nitrate nitrogen concentrations was influenced by the way of water discharge from the reservoir, where bottom floodgates were applied instead of sluice gates working as spillways, which reduced water outflow from the surface layer, which usually contains lower biogenic concentrations [Bus and Mosiej 2013].

Młyny dam reservoir on the Julianpolanka river considerably decreased concentrations of phosphates, nitrates and nitrites, slightly reduced ammonium ion concentrations and electrolytic conductivity values, but increased mean values of BOD_5 and temperature [Wiatkowski 2015]. Michalice reservoir had a similar impact on water quality in the Widawa river. It clearly diminished mean concentrations of nitrates, phosphates and EC values, and slightly lowered concentrations of phosphates and nitrites, but increased average values of the temperature, COD-Cr and ammonium ions [Wiatkowski 2013]. In result of the Milówka stream water flow through Komorów reservoir, concentrations of nitrates and phosphates decreased considerably, dissolved oxygen slightly, whereas the water temperature increased [Wiatkowski 2010].

In Jutrosin lateral reservoir fed by water from the Radęca and the Orla rivers, mean concentrations of dissolved oxygen and BOD_5 increased, water salinity decreased and, except nitrate nitrogen, concentrations of the other studied biogenic indices decreased. In Pakosław lateral reservoir, filled by water from the Orla river, water hardness and salinity decreased, mean concentrations of all analysed biogenic substances and dissolved oxygen lowered, whereas BOD_5 value increased [Przybyła et al. 2014a].

A review paper by Policht-Latawiec at al. [2011] contains an analysis of the impact of 22 dam reservoirs situated mainly in the upper Vistula and Odra basins on the quality of flowing waters. Depending on natural and anthropogenic conditions, an improvement or worsening of some water quality parameters occurred – usually biogenic concentrations were lowering, but also organic pollution (BOD_5 and COD-Mn) were often increasing. Various tendencies occurred also for some oxygen indices [Policht-Latawiec et al. 2011]. Due to not unanimous tendency of water reservoir effect on a change of river water quality, continuation of this type of research is most recommended in order to accumulate as much as possible empirical data, which in future will allow for more general conclusions.

The number of natural and anthropogenic factors affecting the state of surface water quality is considerable, so presented paper focuses only on selected anthropogenic factors.

The aim of the paper is presentation of the most important research issues addressed by series of publications in a thematic cycle concerning the impact of selected anthropogenic factors on shaping of surface water quality. They were divided into five scientific issues, discussing specifically:

– **the impact of various forms of management and use of small uncontrolled catchments on the quality of the runoff water in watercourses, on which a construction of small retention reservoirs is planned [B.1.1; B.1.2; B.1.3],**
– **the impact of changes in agricultural catchment use on the quality of surface waters [B.1.4],**
– **the impact of hydraulic structures on oxygen conditions in river water [B.1.5],**
– **the impact of treated sewage on the receiving water quality [B.1.6],**
– **the impact of artificial water reservoirs on the quality of water in upland rivers [B.1.7; B.1.8].**

Materials and methods

Hydrochemical research in small upland and mountain catchments, in which a construction of small retention reservoirs has been planned, were conducted in 2007-2009, as apart of development grant No. R 12 001 02 financed by MNiSW. From among 65 reservoirs covered by the Small retention Programme… [Program… 2004], 12 small catchments were selected, of which 4 were located per 3 various regions of the Malopolskie province, in the area of Kraków and Wieliczka counties (region 1), Tarnów (region 2) and Jordanów (region 3). The regions differ with some natural habitat factors (the altitude, land relief, precipitations), but the catchments differ most with their land use and management [B.1.1; B.1.2; B.1.3].

Catchments of the first region are situated in the immediate vicinity of Krakow city agglomeration in the: Cholerzyn Depression, Proszowice Plateau and Wieliczka Upland mesoregions. The investigations were conducted on the Szczyrzawy, the Sudół and the Sudół Dominikański streams and in the upper part of the Wilga river catchment. These watercourses flow into the Vistula (the Szczyrzawy and the Wilga) and to the Białucha – a left bank tributary to the Vistula (the Sudół and the Sudół Dominikański). Their areas range from over 6 km^2 (the Szczyrzawy and the Sudół Dominikański) to over 14 km^2 (the Sudół) and almost 23 km^2 (the Wilga). Mean weighted average altitudes (239.8–335,0 m a.s.l.) and average land slopes (4.4–11.1%) point to a mountain character of the catchments. Regarding their management, these are agricultural catchments, because in each of them arable lands grasslands and orchards constitute the highest proportion. They cover from over 72% of the Wilga river catchment to over 93% of the Szczyrzawy stream catchment. Built up areas also constitute a considerable proportion of the area management, because except the Szczyrzawy stream catchment, where they cover the least, i.e. only 4.2% of the area, in the other catchments their proportions range from 12.3 to 13.5%. Soils developed from loess and clay loess occur mainly in these streams' catchments [B.1.1].

Situated in the eastern part of Malopolskie province, on Ciężkowice plateau catchments from the second investigated region, are located between 6 and 15 km south-east of Tarnów city. Our investigations covered the Uniszowski, the Rygliczanka, the Wolninka and the Korzeń streams. Three first ones flow into the Szwedka river, a right bank tributary to the Biała, whereas the Korzeń is a tributary to the Wątok, which also flows into the Biała – a right bank tributary to the Dunajec. The catchments areas vary from over 5 km^2 (the Uniszowa) to over 7 km^2 (the Ryglicznka and the Wolninka streams) to almost 10 km^2 (the Korzeń). Average relative altitudes (298.3–336.0 m a.s.l) and average land slopes fluctuating from 10.9 to 17.5% indicate an upland character of the catchments, although there are obviously more diverse landforms than in the objects located in region 1. Heavy lessive and leached brown soils dominate in all catchments, composed of loess and ordinary loess-like deposits underlain by clay loess. Due to diversification of natural conditions in the catchments of the analysed streams, their land use and management differ. The Uniszowski stream catchment is an agricultural-forestry, whereas the three other forestry and agricultural. The afforestation rate of the individual catchments is from 25.1 (Wolnika) to 54.5% (Uniszowa). Dispersed built-up areas constitute a small portion of their areas, covering between 2.1 and 4.2%, respectively in the Uniszowski and the Wolninka streams. The runoff waters from the catchments in region 2 are under the pressure of natural (e.g. erosion and leaching) and anthropogenic factors connected mainly with farming activities and to a lesser extend with rural settlements and transport [B.1.2].

The catchments of the third region are located in the western part of Malopolskie province, in Sułkowice county and geographically belong to the Beskid Makowski and Żywiecki Mts. They are located in a straight line from 6 to 9 km away from Jordanów town. The analysed Osielczyk stream is order 3 watercourse, the other are order 4. The Bąbola is a left bank tributary to the Łętówka river, which is a tributary to the Raba river. The Osielczyk flows on the right side into the Skawa river – the right bank tributary to the Vistula river. The Mostowy Potok and the Głaza streams are respectively a left bank and right bank tributaries to the Bystrzanka river, which is a tributary to the Skawa river. The catchments areas increase from over 3 to almost 9 km^2, in the following order: the Bąbola, the Osielczyk, the Mostowy Potok and the Głaza. Average absolute altitudes (598.8–684,1 m a.sl.) and average land slopes varying from 18.0 to 22.5% indicate a mountain character of the catchments. Skeletal soils on flysch substratum of loam-clay detritus developed in the investigated catchments both on the agricultural lands and under forests. These are generally shallow soils, locally strongly gleyed, with loam and silt loam granulation. Because of their poor fertility, farming activities are little profitable, which additionally intensifies plots dispersion. The catchments are distanced from traffic routes and reveal a low proportion of ploughlands and settlement areas. Forest and tree-covered areas dominate with a relatively high percentage of grasslands, which developed mainly on the soils excluded from tillage. Forests and tree-covered areas in the Głaza catchment cover over 56% of the area, i.e. the least among the studied catchments, whereas the afforestation rate of the Mostowy Potok catchment reaches 76.0%. Grasslands in both catchments cover respectively 31.1 and 15.6%, while in the Bąbola and the Osielczyk streams – 26.4 and 16.7% [B.1.3].

The hydrochemical research, focused on the threat to water quality and conducted in 12 small retention reservoirs planned in the Malopolskie province, covered 30 indices, including 28 physicochemical and 2 microbiological ones. Directly on-site measured were: pH with CP-104 pehameter, the temperature, content of dissolved oxygen and the degree of oxygen saturation – by means of CO-411 oxygen meter, electrolytic conductivity (EC) – by CC-102 conductometer. The following assessments were made, using referential methods, in the laboratory of the Department of Land Reclamation and Environmental Development, University of Agriculture in Krakow: total suspended solids (ZO) and dissolved solids (SR) concentrations – by means of gravimetric method, calcium (Ca^{2+}), sodium (Na^{+}), potassium (K^{+}), magnesium (Mg^{+}), total iron ($Fe^{2+/3+}$) and manganese (M^{2+}), chromium (Cr^{6+}), zinc (Zn^{2+})' cadmium(Cd^{2+}), copper (Cu^{2+}), nickel (Ni^{2+}) and lead (Pb^{2+}) ions concentrations – using atomic absorption spectrometry method on UNICAM SOLAR 969 spectrometer, concentration of nitrogen in the ammonium form ($N\text{-}NH_4^{+}$), nitrite ($N\text{-}NO_2^{-}$) and nitrite ($N\text{-}NO_3^{-}$) form, as well as concentrations of total phosphorus (P_{total}), phosphates (PO_4^{3-}) and chlorides (Cl^{-}) – by means of flow colorimetric method on FIAstar 5000 apparatus, sulphate (SO_4^{3-}) concentration – using precipitation-gravitational method, five-day oxygen demand (BOD_5) – using Winkler titration method, chemical oxygen demand (COD-Mn) using titration method following boiling with $KMnO_4$. Coliform and faecal coliform bacteria number was assessed by means of membrane filtration method on media with lactose at the temperature of 37 and 44^{o}C with tolerance 0.5^{o}C. On the basis of $N–NH_4^{+}$, $N–NO_2^{-}$ and $N–NO_3^{-}$ assessments the concentrations of ammonium (NH_4^+), nitrite (NO_2^-) nitrate (NO_3^-) ions were calculated. All measurements and assessments were conducted using reference methods on randomly chosen dates – heavy metal concentrations and coliform, faecal coliform bacteria numbers were assessed once a three months, whereas the other indices once a month.

As a part of desk studies, a detailed physiographic characteristics of the analysed catchments was developed using GIS tools. Survey interviews were conducted, the territory inventory was made and natural and anthropogenic conditionings were identified, which might have shaped water quality in the individual catchments. On the basis of hydrochemical research results, the minimum and maximum values of individual water quality indices were determined. The arithmetic means, variance coefficients, standard deviations, percentiles 90 and the percentage of the indices in the individual water quality classes were computed. Water quality state in the streams was determined on the basis of the following Regulations of the Minister of the Environment:

- on the classification for present status of surface water and groundwater, how to conduct monitoring, and how to interpret the results and presentation of these waters of 11 February 2004 [Rozporządzenie… 2004],
- on the method of classification of the status of the homogenous surface water bodies of 20 August 2008 [Rozporządzenie… 2008],

Water quality was assessed using pollution coefficient suggested by Burchard and Dubaniewicz [1981]. The functional values and eutrophication hazard to flowing waters were determined on the basis of allowable values of the indices included in the normative values stated in the applied regulations of:

- the Minister of the Environment of 4 October 2002 on the requirements for inland waters which are the fish habitat under natural conditions [Rozporządzenie… 2002a],
- the Minister of the Natural Environment of 27 November 2002 on requirements to be met by surface water used for public supply of water intended for human consumption [Rozporządzenie… 2002b],
- the Minister of Environment of 23 December 2002 on the criteria of identification of waters vulnerable to pollution with nitrogen components from agricultural sources [Rozporządzenie… 2002c],
- the Minister of Health 16 October 2002 on the requirements for bathing water of [Rozporządzenie… 2002d].

The forecast of trophicity for the planned reservoirs was estimated on the basis of hydraulic loading and annual phosphorus load inflowing with water [B.1.1; B.1.2; B.1.3].

Hydrochemical research connected with the assessment of the impact of changes in the catchment management on surface water quality were conducted in 1995–1996 and 2010–2011 in Rzyki G catchment with the area of 47.50 ha. It is situated in Andrychów district, in the western part of Malopolskie province, in the area of the Beskid Mały Mts. Only one watercourse, 0.575 km long is flowing in a clearly shaped valley. It is a left bank tributary to the Wieprzówka river. Mean weighted average catchment altitude is 425 m a.s.l., whereas average land slope is 12.2%, which evidences its upland character. The catchment is covered by shallow skeletal and strongly acid dystrophic brown soils, characterized by a considerable compactness, big capillary capacity and small leachability. Rzyki G catchment is a typically agricultural one in 1995–1996 the ploughlands, grasslands and fallows covered a total of 84.9% of its areas, whereas in the second investigated period – 82.9%. [B1.4].

Water samples were collected in a measurement point situated in the hydrometric cross section of the Rzyki G. watercourse. On site and in the laboratory of the Department of Land Reclamation and Environmental Development, UR Krakow assessed were: pH, ammonium nitrogen ammonium($N–NH_4^+$) and nitrate ($N–NO_3^-$) nitrogen, phosphates (PO_4^{3-}), sulphates (SO_4^{2-}), chlorides (Cl^-), calcium (Ca^{2+}), sodium (Na^+), potassium (K^+), magnesium (Mg^{2+}) and total iron ($Fe^{2+/3+}$). The reference methods applied for the assessments of these physicochemical indices were described above. Basic descriptive statistics were calculated for each indicator and the significance of differences between the values of indices from both periods of research was estimated using U Mann-Whitney non-parametric test. Quality of the runoff water from the catchments was assessed in compliance with the guidelines of the Regulation of the Minister of the Environment dated 9 November 2011 on classification of ecological status, ecological potential and chemical status of homogeneous parts of surface water [Rozporządzenie …2011]. Apart from hydrochemical research, a through inventory of the terrain was conducted. Ortophotomaps, topographic maps and GIS tools were used to develop two maps of the land use and physiographic characteristics of Rzyki G catchment [B.1.4].

Studies on the hydrotechnical structures impact on the oxygen conditions in surface water were realized along over 17.5 km long reach of the Wschodnia river, which a right bank tributary to the Czarna Staszowska. The Wschodnia river, about 48.50 km long, whose catchment area is 680.3 km^2, has its sources on the Szydłów upland in Zreczach near Chmielnik (260.00 m a.s.l) and below Druginia village (302,00 m a.s.l). The river is flowing along the Połaniecka Basin axis through the territories of six districts of Świętokrzyskie province. From its sources to the confluence with the Sanica – its largest left bank tributary, the Wschodnia river has the character of a mountain carbonate stream with fine grain substrate on loess and loess like (type 6), whereas along the other reach it is a small silicate-western upland river, type 9. It channel, 1–18 m wide and 0.3–2.5 m deep has small sinuosity, which in some places is totally straight. The flat valley, between 0.6 and 1.5 km wide, is covered mainly by meadows and pastures with small pine forest stands or riparian tree stands. On the other hand, the catchment has more diverse land forms and land use – ploughlands dominate, which together with grasslands cover about 74.4% of the area, afforestation rate slightly exceeds 16% whereas almost evenly distributed built up areas cover 9.5% of the catchment area [B.1.5].

12 small hydraulic structures in at least moderate technical condition, including 4 weirs, 6 drop structures, 1 riffle and 1 drop structure with riffle were selected for the investigations. The structures with inventory numbers of the Świetokrzyski Directorate of Land Reclamation and Infrastructure in Kielce are situated at the following kilometres of the Wschodnia river course: 8 – reinforced concrete weir (without valves) with a drop structure (p = 1.40 m) at km 7+875; 10 – reinforced concrete weir (h_{max} = 1.20 m – no damming during the research) with a drop structure (p = 0.70 m) at km 11+675; 15 – reinforced concrete weir ($h_{max.}$ = 1.50 m – no damming during the research) with a drop structure (p = 0.65 m) at km 14+200; 17 – concrete drop structure (p = 0.60 m) at km 14+950; 19 – riffle of stone riprap at km 16+300; 25 – concrete step (p = 1.00 m) with a drop structure at km 19+625; 27 – reinforced concrete step (p = 1.20 m) at km 20+150; 35 – concrete drop structure (p = 0.50 m) with riffle of stone riprap at km 23+450; 37 – concrete drop structure (p = 0.50 m) at km 23+750; 38 – reinforced concrete weir ($h_{max.}$ = 1.50 m – no damming during the research) with drop structure (p = 0.65 m) at km 24+150; 40, 41 – concrete drop structres (p = 1.00 m) located respectively at km 24+875 and 25+400.

22 measurement series were conducted during the vegetative periods of the years 2006–2008 in various meteorological conditions. Concentrations of dissolved oxygen and values of the degree of water saturation with oxygen were measured using CO-411 oxygen meter at each of the investigated structures. The measurements were conducted above the construction at the distance before the backwater reach, immediately before the construction and 50 m below the construction. The empirical data base was subjected to statistical analysis. The significance of differences in mean concentrations and water saturation with oxygen among the 3 measurement points was estimated using parametric t-Student test for dependent samples (α = 0.05), separately for each construction and jointly for all studied hydraulic structures. Moreover, correlation relationships were determined between the increases in concentrations and water saturation with oxygen after water flowing through the structures and the elevation of water table and mean values of these 2 oxygen indices before backwaters. The significance of correlation coefficients was verified by means of t-Student test. Apart from the main part of the studies, also a physiographic characteristic of the Wschodnia river catchment was made. Moreover, water quality along individual reaches of the Wschodnia river was assessed on the basis of 13 physicochemical indices [Rozporządzenie… 2008], as well as the degree to which self-purification processes occur in the river [B.1.5].

Annual investigations on the impact of treated sewage on the quality of the receiving water were conducted along the Breń river reach, on which a drain collector from the mechanical-biological sewage treatment plant is located. Its catchment with the area of 717 km^2 is situated in the Sandomierz Basin and covers the north-east part of the Malopolskie province and north-western part of the Podkarpackie province, The Breń river is about 52 km long and as the right bank tributary to the Vistula river is the 2nd order watercourse. It is flowing mainly through agricultural lands and Dąbrowa Tarnowska city (Dąbrowa county), where treated sewage is discharged into it. The sewage treatment plant is situated on the right bank of the Breń river. It was constructed in the sixties of the 20th century, but due to its low efficiency and because it did not meet the European Union requirements, it was extended and modernized in 2007–2008. Its current throughput during the rainless period is: $Q_{dśr.} = 3000\ m^3 \cdot d^{-1}$, $Q_{dmax.} = 3750\ m^3 \cdot d^{-1}$, whereas during the rainy period: $Q_{dśr.} = 4600\ m^3 \cdot d^{-1}$, $Q_{dmax.} = 5550\ m^3 \cdot d^{-1}$. It has been adjusted to receive a pollutant load from a maximum of 20000 RLM. It is composed of one modern building housing all technological appliances, hydroponic lagoon, administrative and social rooms and installation for hygienization and dewatering of sludge. The mechanical part is composed of: a wedge wire screen, sewage pumping station, grit chamber screen, screenings hygienization unit and sand washer. Biological treatment is conducted in circulation chambers of activated sludge, secondary sediment tanks, container for stabilization and thickening of excessive sludge and sludge dewatering station. The sewage treatment plant in Dąbrowa Tarnowska uses a legal water permit for specific use of waters through discharging treated municipal sewage to the Breń river at km 12+030. According to the legal water permit the waters discharged from the treatment plant cannot contain chlorinated hydrocarbons or solid wastes. Moreover, they must meet the requirements concerning the maximum values of temperature 35ºC, pH – 6.5–9.0, COD–Cr – 125 mg $O_2 \cdot dm^{-3}$, BOD_5 – 25 mg $O_2 \cdot dm^{-3}$ and total suspended solids – 35 mg$\cdot dm^{-3}$, as well as the requirements for the reduction of total phosphorus and total nitrogen – respectively higher than 40 and 35% [B.1.6].

During the period from May 2014 to April 2015, hydrochemical tests were conducted every month in three measurement points. The first and the third were located on the Breń river, respectively 30 m above (km 12+060) and 400 m below (km 11+630) the treated sewage discharge point, whereas the second was on the outlet collector from the treatment plant. Water temperature, pH, concentrations of dissolved oxygen and electrolytic conductivity (EC) were measured directly on-site, whereas BOD_5, COD-Mn, phosphates (PO_4^{3-}), total phosphorus ($P_{ogólny}$), ammonium nitrogen ($N–NH_4^+$), nitrites (NO_2^-), nitrate nitrogen ($N–NO_3^-$), nitrates (NO_3^-), soluble solids, phosphates (SO_4^{2-}), chlorides (Cl^-), calcium(Ca^{2+}) and magnesium (Mg^{2+}) were determined in a laboratory. Basic descriptive statistics were calculated for each analysed physicochemical index for the whole annual period of research, for the winter half-year (October–March) and for the summer half-year (April–September). The assessment of treated sewage impact on water quality in the Breń river was conducted by means of U Mann-Whitney test ($\alpha = 0.05$), which involved the comparison of the indices tested before and below the treated sewage discharge. The same non-parametric significance test was used to confront, separately for each measurement point, the values of individual indices between the half-years. In order to assess the efficiency of sewage treatment, the values of selected investigated physicochemical indices of the outflow water from the treatment plant (point 2) were compared with the admissible values stated in the legal water permission and in the Minister of the Environment Regulation of 18 November 2014 on the conditions which must be fulfilled by the sewage discharged into water or earth and on the substances particularly harmful for aquatic environment [2014b]. Moreover, for comparison, in each point the ecological status, usability for fish, andl eutrophication hazard were assessed – in compliance with the Regulations of the Minister of the Environment [Rozporządzenie…2014a, 2002a and 2002b] [B.1.6].

Studies on the impact of artificial water reservoirs on surface water quality were conducted on a small lateral reservoir Nowy Zalew and on a large Goczałkowice dam reservoir [B.1.7; B.1.8].

Nowy Zalew reservoir is situated in Koniecpol town in the Śląskie province, Czestochowa county. Considering the natural conditions, it is situated in the Natura 2000 habitat protection area named "Upper Pilica Valley". The reservoir has the water table area of 7.54 ha and capacity of 126 thousand m^3. It is located in the immediate vicinity of the right bend of the Pilica river. Water intake and outflow are maintained by means of a five-span concrete weir situated on the Pilica and Kopanka channel. The water table regulation and water draining from the reservoirs is done using the MN-4 type outlet box. Water outflows from Nowy Zalew in a short channel and then through the embankment culvert returns to the Pilica. Due to its urban location, during the summer period, the reservoir fulfils mainly recreational function. Guarded bathing facilities together with pedal boat and kayaks rent were established in the area, as well as "grilling party" sites. After the summer season the reservoir is used by anglers. The terrain by the reservoir has been sown with grass mixture, but finally is intended for sports-and recreation facilities, which will be constructed for the inhabitants of Koniecpol city [B.1.7].

The Goczałkowice Reservoir was constructed in 1955 by partitioning the Small Vistula river by a frontal earth dam at km 43+092 and cutting off the lagoon by a lateral dam. The reservoir is situated in the Śląskie province, in the southern part of Pszczyna county, in Goczałkowice-Zdrój district. Total reservoir capacity is 161.25 hm^3, including equalization storage and flood capacities of respectively 105.6 and 43.2 hm^3. The reservoir has the area of 32 km^2 and is fed by waters from the Vistula river (82% of carried in waters), the Bajerka river (4%), by waters from ditches draining the riparian areas (10%) and from other sources, e.g. atmospheric precipitations (4%). It is a multi-functional reservoir, whose tasks include in the first place water supply for the Silesian agglomeration and flood protection of the Vistula river valley. Its other functions comprise: fish farming, feeding low flows and the nature protection – in 2004 the reservoir was included in the European Natura 2000 network of bird protection under the name of "The Upper Vistula Valley". Moreover, the western and southern parts of the reservoir are a part of the Natura 2000 habitats and sites protection areas under the name "The Goczałkowice Reservoir – the Vistula and Bajerka rivers mouth". Since 2010 recreational and sport sailing have been permitted in its area. The Goczałkowice Reservoir catchment to the dam cross section has the area of 523.1 km^2 and constitutes the upper part of the Vistula river basin, covering the mountain and upland areas of the Beskidy Mts.

and Oświęcim Basin. Four cities are situated in the catchment area: Wisła, Ustroń, Skoczów and Strumień, the built-up area covers 51 km^2, which constitutes 9.8% of the area [B.1.8].

Hydrochemical studies were conducted in 2011. In both reservoirs water was sampled on the inflow and outflow, and additionally in three points located in the Goczałkowice Reservoir Bowl, distributed regularly along the Vistula transect. 18 (Nowy Zalew) and 20 (Goczałkowice Reservoir) water quality indices from the physical, acidification, salinity, oxygen, biogenic groups and metals were determined using reference methods on site and in the laboratory of the Department of Land Reclamation and Environmental Development. Basic descriptive statistics were determined for all analysed water quality indices, separately for each measurement point [B.1.7; B.1.8].

For Nowy Zalew, in both points the ecological status was assessed in compliance with the ministry guidelines [Rozporządzenie… 2008], suitability for the salmonid and cyprinid habitats under natural conditions [Rozporządzenie… 2002a] and for bathing [Rozporządzenie… 2002d]. Moreover, the hazard of surface waters eutrophication was determined [Rozporządzenie… 2002c]. The analyses allowed for an assessment of the reservoir effect on surface water quality [B.1.7]. Due to a more extensive empirical data base resulting from higher number of measurement points, more advanced analysis was conducted for the Goczałkowice Reservoir. Statistical significance of differences between values of indices registered in different measurement points was estimated by parametric t-Student test, on the level $\alpha = 0.05$. Cluster analysis was conducted using Ward agglomeration method to group measurement points regarding similarities in water quality. Ecological potential was assessed in each measurement point [Rozporządzenie… 2014a], but due to little diversification of water quality, for comparison the analysis was based on extreme values (maximum or minimum) not average ones [B.1.8].

Research results

While researching the first problem I demonstrated that water quality in small catchments is considerably affected by their management and type of land use, as well as by the anthropopressure level. On the basis of studies, it was established, that all catchments in the tree regions of Malopolska have small areas, from over 3 km^2 to about 23 km^2. They differ regarding their altitude and land configuration. The catchments located in the Beskid Makowski and Żywiecki Mts. (region 3) distinguish themselves by the average highest altitude above the sea level, the highest precipitations, but also by the greatest average land slope, afforestation rate and density of the hydrographic network. Obviously lower values of the above mentioned factors occur in the catchments situated in region 2, whereas the catchments in region 1 are characterized by on average the lowest values of these factors. There is also a considerable diversification among the catchments concerning the danger of surface water erosion. All catchments of region 2 and the Wilga river basin in region 1 require the first, urgent degree of ground protection against erosion. The second urgent degree of protection is necessary in the Sudół Dominikański catchment – region 1 and in three catchments of region 3. A less urgent – third degree of ground protection against erosion is required in the Szczyrzawy and the Sudół streams (region 1) and the Mostowy Potok from region 3. The analysed catchments are also greatly diversified regarding their use. In region 1 they are agricultural catchments, because in each ploughlands, grasslands and orchards prevail. The proportion of built-up areas is also high. Forests have a considerable, i.e. 25% share in the areas of catchments from region 2, yet agricultural management dominates. Forest and tree covered areas are prevailing in the catchment in region 3, while the proportion of grasslands is also relatively high. Considering the settlement development density, it was established that from among the twelve catchments two have a settlement-agricultural character (the Sudół and the Sudół Dominikański), one has a forest-settlement-agricultural character (the Wilga), one is an agricultural catchment with dispersed development (the Szczyrzawy), three are forest-agricultural with dispersed development (the Uniszowa), two are agricultural-forest with sparse compact development (the Mostowy Potok and the Głaza) and two, the Bąbola and the Osielczyk are typically agricultural-forestry catchments. The catchments in the region 1 are characterised by on average the greatest population density, the highest proportion of ploughlands and built-up areas, the largest number of farms per 1km^2 and the highest density of asphalt and paved roads. Among the analysed objects, the most weakly anthropogenic are the catchments in the Makowski and Żywiecki Beskid (region 3). It shows, that the catchments in region1 are strongly transformed anthropogenically, therefore they are characterized by a high level of the environmental pressure. The catchments in region 2 are much less burdened anthropogenically , whereas in the catchments of region 3 a relatively low level of anthropopressure occurs [B.1.1; B.1.2; B.1.3].

In accordance with the Regulation of the Minister of the Environment of 2004 [Rozporządzenie… 2004], water quality was assessed on the basis of 27 indices, taking into consideration maximum values of heavy metal concentrations and the number of coliform and faecal coliform bacteria, and the percentiles of 90 other indices. Taking into consideration the class comprising 90% of design values used for the assessment of the indices, it may be stated that only under conditions in the catchments of the Bąbola the Mostowy Potok (region 3), surface waters are of good quality, i.e. class II. Surface waters in the catchments of eight streams, including two from region 3, i.e. the Osielczyk and the Głaza, all from region 2 and two from region 1 – the Szczyrzawy and the Wilga, are of satisfactory value (class III). On the other hand, runoff waters from the watercourses the Sudół and the Sudół Dominikański situated in region 1 should be counted among poor quality waters – class V. Despite the fact, that water from eight watercourses was classified to class III, it should be noted that the number of indices worsening water quality in the catchments of region 1 was much higher than in region 2.

Water quality assessed according to the pragmatics of the Minister of the Environment Regulation of 2008 [Rozporządzenie… 2008] looks much better, according to hich the quality of water bodies is the resultant of its ecological and chemical status. The ecological status of the studied streams was assessed by comparison with the values admissible for individual classes, percentiles 90 of 16 analysed physicochemical indices and maximum value of 3 substances particularly harmful for the aquatic environment, i.e. Cr^{6+}, Zn^{2+} and Cu^{2+}, whereas the chemical status was determined on the basis of maximum Cd^{2+} concentration and mean values of Ni^{2+} and Pb^{2}. On the basis of the data analysis conducted in this way it was stated that the waters of the Uniszowski stream from region 2 and three streams from region 3 (the Bąbola, the Osielczyk and the Mostowy Potok) may be classified to class I of very good ecological status and to good chemical status. Waters in the other watercourses in region 2 and in the Szczyrzawy and the Głaza, respectively from regions 1 and 3 have been classified to quality class II (good ecological status) and to good chemical state. The Wilga river waters belong to water quality class III (moderate ecological status) and have good chemical state, whereas waters in the Sudół and the Sudół Dominikański streams, although also classified to class III, do not reach a good chemical status. Generally the status of water bodies of all researched watercourses from regions 2 and 3 and from the Szczyrzawy stream is good, while the other 3 watercourses is bad.

A considerable diversification in water quality of individual streams has been also confirmed by the pollution coefficient computed my means of Burchard and Dubaniewicz formula. This analysis shows that irrespective of the number of indices considered in the assessment, waters flowing in region 3 and in the Uniszowski stream are classified to clean waters. On the other hand, waters in the Szczyrzawy, the Rygliczanka and the Wolninka streams are classified to visibly polluted waters, while in the Sudół and the Sudół Dominikański to sewage. The Wilga river waters, depending on the number of indices considered, were regarded as visibly or slightly polluted, and in the Korzeń stream as markedly or strongly polluted. A stronger pollution of water in the Sudół and the Sudół Dominikański streams is determined by the outflows from the sewage treatment plant situated in the catchment area, whereas in case of the Korzeń stream – the dominating ploughlands in the catchment, favouring water erosion and localisation of several households in a close vicinity of the watercourses.

Only water in the Bąbola stream meets the requirements posed for the natural salmonid and cyprinid habitats. For the salmonids they were not met by water in the Mostowy Potok because of elevated nitrite concentration. For the same reason waters flowing in all watercourses in region 2 and in the Osielczyk, the Głaza, the Szczyrzawy and the Wilga do not create conditions favourable for either of the fish species. The runoff waters from the catchment of the Sudół and the Sudół Dominikański do not meet the habitat requirements, either, due to 5 indices, including nitrites.

Water from all streams in the Tarnów and Suski regions may be used for supply of water for human consumption, but it must be first subjected to a typical or high performance processes of physical and chemical treatment, appropriate for waters of category A2 or A3. On the other hand, the runoff waters from the catchments in region 2 (suburban and urban region of Krakow) cannot be used for this purpose, because of a too strong pollution they do not meet the requirements of either water treatment categories.

The requirements for the open swimming pools have been fulfilled in 9 out of 12 studied watercourses. In case of the Wolninka, functional qualities are worsened by incidental phosphate concentrations, whereas waters in the Sudół and the Sudół Dominikański streams do not meet the due to exceeded allowable values of respectively 6 and 8 physicochemical indices.

Eutrophication threat to waters flowing in the analysed streams was assessed on the basis of total phosphorus, nitrate nitrogen and nitrates, whose mean annual concentrations were compared with the standards, above which eutrophication occurs [Rozporządzenie… 2002c]. On the basis of the data analysis it was stated that at present waters neither of the watercourses in regions 2 and 3 are threatened with eutrophication. Moreover, this hazard does not appear for the Wilga river waters, whose catchment is situated in region 1. On the other hand, because of too high nitrate indices in the Szczyrzawy stream water and total phosphorus concentration in the Sudół and the Sudół Dominikański streams, it may be inferred that waters flowing in these watercourses are susceptible to eutrophication.

The forecast of water trophic level was developed basing on reservoir parameters taken from the Small Retention Programme…[Program… 2004] and own studies on total phosphorus concentrations in the watercourses which feed them. On the basis of calculated hydraulic loads of the reservoirs and loads of their surface with total phosphorus it was established that all reservoirs situated in region1 would be eutrophic, whereas in the two other regions would have a mesotrophic character.

Generally, the quality and functional values of waters draining the investigated catchments located in the Beskid Makowski and Beskid Żywiecki Mts, except the Bąbola stream, only to some degree was worsened by the concentrations of nitrites and total iron and coliform bacteria number. The same factors and additionally COD-Mn values and manganese concentrations, but far more frequently, affect worsening of water quality in the catchments situated on the Ciężkowice Plateau and in the Wilga stream. Moreover, a heightened water turbidity following intensive rainfall is observed in these catchments, which results from loess soil erosion. High values of the previously mentioned indices were also registered in the Szczyrzawy stream water and due to a considerable proportion of arable lands in this catchment, high concentrations of phosphates and nitrates were also noted. In case of the Sudół and the Sudół Dominikański catchment located closest to Krakow, almost all analysed indices deteriorated water quality and its functional values. Unlike the others, in the catchments of these watercourses also elevated concentrations of some heavy metals were registered [B.1.1; B.1.2;B.1.3].

My investigations addressing the **second issue** revealed that changes in the upland catchment area management also affect the modification of the quality parameters in surface waters. In the years 1995–1996 ploughlands prevailed in the land use structure in Rzyki G Catchment, constituting 68.7%. Forests and tree covered areas and grasslands covered respectively 8.4 and 16.2%

of its area. Non-agricultural lands occurred sporadically (2.4%), whereas 4.3% of the area was used for compact development. In the years 2010–2011 arable fields occupied only 22.1%, whereas the grassland and wasteland areas increased (total 56.7%). The forest and built up areas also increased slightly, respectively to 11.1 and 6.0% [B.1.4].

On the basis of data analysis it was found that in result of transformation of a considerable acreage of arable lands into permanently turfed areas, the concentrations of 7 out of 11 studied indices, i.e. ammonium and nitrate nitrogen, phosphates, sulphates, calcium, chlorides and iron decreased considerably over 15 years. Although water quality determined on the basis of mean values [Rozporządzenie… 2011] classified the waters in both periods to class I of very good ecological status, still in single samples during the pre-transformation period, values of ammonium nitrogen and phosphates classified the waters to below good status and in case of nitrate nitrogen to class II. Undoubtedly, it was caused on one hand by the increase in the acreage of lands no longer used for agriculture where fertilization was stopped, on the other the area covered by grasses has greater hydraulic roughness and better protects the soil against surface runoffs and limits its erosion. Therefore, a change of land use in Rzyki G catchment, where big land slopes occur together with compact and little permeable substratum, led to a considerably limited leaching of chemical components from the soil to surface waters [B.1.4].

My research addressing the **third issue** verified the hypothesis that in result of water flowing though small (damming and regulating) hydraulic structures oxygen conditions in the river below the dam improve in a statistically significant degree. On the basis of conducted investigations it was found, that the increased concentrations of dissolved oxygen and water saturation with oxygen occurred in water below each structure, as compared with the values measured before the structure above the backwater range. Except for one case, the difference were statistically significant on the level $\alpha = 0.05$. On average the highest, i.e. by 0.74 $mg \cdot dm^{-3}$ increase in oxygen occurred at weir no.10, whereas the lowest at concrete drop structure no. 25 (0.24 $mg \cdot dm^{-3}$). Regarding water saturation with oxygen, one average its highest increase was observed by the structures no.8 and 10 (7.0% each) whereas the lowest and statistically non-significant by the structure no. 25 – 1.9%. Analysis of all structures together revealed that after flowing through them water contained on average by 0.50 and 0.40 $mg \cdot dm^{-3}$ significanlty more of dissolved oxygen than, respectively before the backwater and immediately before the structure. Mean water saturation with oxygen was also significantly higher below the structure. It was stated, that in result of water flow through the structure, oxygen saturation increased on average by 4.6 and 3.8% – in relation to the values before the backwater and before the structure. It was also observed, that slightly more favourable conditions were in the water immediately before the structures than before backwaters [B.1.5].

The search for correlation relationships between mean increases of concentrations and the pool elevation revealed that in case of such small hydraulic structures the relationship between these factors does not occur – correlation coefficient r = 0.08. no statistically significant relationship (r = 0.27) was registered, either between the mean increases in water saturation with oxygen and the pool elevation of the structure. On the other hand, a strong (r = -0.71) and medium (r = -0.63) correlations were stated between the average increases in concentrations and water saturation with oxygen and mean water saturation with oxygen before backwater. It evidences, that the more water is saturated with oxygen above the backwater (in relation to the full saturation), the effect of its increased saturation in result of flow through small hydraulic structures decreases the more significantly.

Water inflowing to two hydraulic structures closest to the outlet had very good ecological status, whereas in the other cases, due to elevated concentrations of calcium was classified to class II. Analysing the values and concentrations of 13 physicochemical indices studied along the Wschodnia river length, I found that in case of 6 of them a clear decreasing tendency becomes apparent with the water current. It evidences self-purification processes occurring in water. It was confirmed particularly by nitrate nitrogen and total phosphorus concentrations, which between the highest and lowest situated structures are diminishing respectively two and over there times. Therefore, it may be surmised that one of the factors affecting such intensive self-purification processes is oxygen supplied on a regular basis in result of water flowing through the structures, which causes a change of its flow from laminar to turbulent [B.1.5].

My investigations of **the fourth** research problem focused on the influence of treated sewage on the receiving water quality. On the basis of data analysis it was stated that pollutant concentrations in treated sewage discharged to the Breń river did it exceed the values stated in the legal water permit, wheras the requirements of the Regulations of the Minister of the Environment [Rozporządzenie… 2014b] were exceeded only sporadically in the winter-spring period for ammonium nitrogen, i.e. 10 $mg \cdot dm^{-3}$. Small dynamics of seasonal changes of physicochemical indices in treated sewage evidences a considerable and independent of the air temperature efficiency of the treatment plant operation. Comparing the results of treated sewage results with the normative values for surface waters [Rozporządzenie… 2014a] it may be stated that they did not meet the requirements for class II, which means that their ecological status was below good. It was owing to BOD_5, PO_4^{3-}, $N–NH_4^+$ and $N–NO_3^-$, which exceeded by several hundred percent the normative values for class I. Average values of COD-Mn, total phosphorus, dissolved solids and electrolytic conductivity met the requirements for class II, whereas the other for class I [B.1.6].

The ecological state of water in the Breń river above the sewage treatment plant determined on the basis of physicochemical indices was good, water quality was only slightly worsened by mean values of COD-Mn and $N\text{-}NO_3^-$, which exceeded the admissible normative values for quality class I respectively by 0.4 mg $O_2 \cdot dm^{-3}$ and 1.08 $mg \cdot dm^{-3}$. Increased mean values of a majority of studied indices were registered after the discharge of treated sewage, among others BOD_5 values grew by 1.4 mg $O_2 \cdot dm^{-3}$, COD-Mn by 1.4 mg $O_2 \cdot dm^{-3}$, PO_4^{3-} by 0.186 $mg \cdot dm^{-3}$, P_{total} by 0.061 $mg \cdot dm^{-3}$ and $N–NH_4^+$ by 0.769 $mg \cdot dm^{-3}$. Only for sulphates a decrease in mean concentration by

1.7 mg·dm^{-3} was noted. In result of increased pollution, water in the Breń river had the ecological state below good.

Treated sewage affected the increase in 12 from among 17 analysed physicochemical indices in the Breń river, of which in 8 cases the dependencies were statistically significant: PO_4^{3-}, P_{total}, $N\text{–}NH_4^+$, NO_2^-, EC, dissolved solids, Cl^- and Mg^{2+}. Because of BOD_5 and ammonium nitrogen the quality class changed from I to II and due to phosphates very good ecological state changed into below good. The analysis of the significance of differences between the values for the winter and summer half year revealed that in both measurement points situated on the Breń river the seasonality of changes occurring in clean surface waters was disturbed for some indices. However, as might have been supposed more natural seasonal tendencies occurred in water above the treated sewage discharge. Considerable nitrite concentrations caused that waters along the whole studied reach of the Breń river did not meet the requirements for the salmonid and cyprinid fish, but better habitat conditions were in the river above the outlet collector. High annual nitrate and nitrate nitrogen concentrations show that at the present physicochemical state of waters, there is a risk of eutrophication processes in the Breń river. Moreover, treated sewage is characterized by a considerable trophicity and also its mean concentration of total phosphorus exceeded the critical value of 0.25mg ·dm^{-3}. Obtained results confirm, that the discharge of treated sewage unfavourably affects the physicochemical state of the receiving waters. Despite the unsatisfactory effect of the sewage treatment plant, there is no doubt that the water quality in the river would be much worse if the untreated municipal sewage was discharged [B.1.6].

While investigating the **fifth** research problem, I strived to assess the impact of artificial water reservoirs on water quality in upland rivers. My research in this respect covered a small lateral reservoir Nowy Zalew and large dam reservoir called the Goczałkowice Reservoir [B.1.7; B.1.8.].

Basing on the analysis of results of research conducted on Nowy Zalew reservoir it was found that mean arithmetic values and medians of the temperature and pH, both on the inflow and outflow were almost identical. Also, irrespectively of the water sampling point, concentrations of SO_4^{2-}, Cl^-, Mg^{2+}, $N\text{–}NH_4^+$, Mn^{2+}, Na^+ and K^+ were on a similar and very good level. On the other hand, on average almost twice lower concentrations of $N\text{–}NO_3^-$, NO_3^- and $Fe^{2+/3+}$ and five times lower concentrations of total phosphorus were registered on the outflow. The other investigated indices, except for dissolved oxygen, had the values on average almost 15% higher than in the water inflowing to the reservoir. Dissolved oxygen concentrations were on average by about 11% higher on the outflow, which only confirms a favourable effect of the reservoir on surface waters quality. Greater amounts of oxygen may be associated with the fact, that it is a shallow and non-stratified reservoir, therefore no oxygen deficits occur by its bottom. On the other hand, additional amounts of oxygen during the period of the research might have originated from waving of the water table, i.e. from intensified oxygen diffusion from the atmospheric air and from the photosynthesis of plants growing on the reservoir banks [B.1.7].

Waters in both measurement points had good ecological state (class II), however on the outflow from Nowy Zalew reservoir the class was influenced by $N–NO_3^-$ concentrations, while on the inflow additionally dissolved oxygen concentrations. The inflowing and outflowing waters met the requirements for open swimming pools and for natural habitat for cyprinid fish. At present the reservoir is not threatened with eutrophication, but it may be in future, because even now mean concentrations of nitrate nitrogen and nitrates in the inflowing water are close to critical values, i.e. respectively 2.2 and 10mg $\cdot dm^{-3}$. A planned change of the meadowland area surrounding the reservoir in order to create leisure and relaxation facilities for Koniecpol city poses additional hazard [B.1.7].

On the basis of dendrograms obtained in result of conducted cluster analysis it was established that, considering all analysed indices jointly, quality of water outflowing and inflowing by the Small Vistula river to the Goczałkowice Reservoir revealed some similarity, but quite distinctly differed from the quality of water stored in the reservoir. It would evidence a small impact of the reservoir on the values of physicochemical indices of the river water, therefore detailed analyses were performed for individual groups of quality indices. On the basis of the analysis conducted in this way a strong resemblance is visible between the values of physical and oxygen indices and metals, but biogenic and salinity indices differ greatly on water inflow to and outflow from the reservoir. Partially the results of cluster analysis were confirmed by t-Student test of which it results that after flowing through the reservoir, nitrite and nitrate nitrogen concentrations decreased significantly in the Small Vistula river water, which was statistically confirmed on significance level $\alpha = 0.05$. The reservoir influenced also a decrease in the concentrations of phosphates, total phosphorus, total iron and majority of salinity indices, but slightly worsened oxygen conditions, however it was not statistically significant. The effect on smaller amounts of oxygen may be also sought in the fact, that some amount of water is drained from the reservoir by the bottom outlets. This method of water drainage causes also, that despite a big reduction of phosphates, phosphorus, total iron and manganese, only slightly smaller declines in their concentrations were noted in the water outflow from the Goczałkowice reservoir than on the inflow (probably due to deposition in bottom sediments). Ecological potential of the water inflowing to the reservoir and in its middle part was below good – in the first case due to BOD_5 values and in the second because of decreased concentration of dissolved oxygen caused by algae bloom. On the other hand, on the outflow and in two other points located in the reservoir, water ecological potential was good (class II). Taking into consideration results of all conducted analyses it may be stated that generally the Goczałkowice Reservoir positively affects quality parameters of the Small Vistula river water, particularly regarding a decline in concentrations of some biogenic substances [B.1.8].

Conclusion

The most important achievements from the research presented in the monothematic publication cycle : "The impact of selected anthropogenic factors on surface water quality shaping in upland and mountain catchments", constituting an important contribution to the development of the discipline *environmental protection and development*, comprise:

1. Water quality in selected watercourses included in the Small Retention Programme of Malopolskie Province depended strongly on the use and management of the catchment areas. The best quality waters were outflowing from the catchment with highest afforestation rate and little fertile soils. Moderately polluted waters were flowing in the water curses draining extensively utilised agricultural lands, in the catchments without livestock production. Urbanised areas, particularly those with compact development, i.e. urban and suburban ones, inflicted the highest negative pressure on water quality.
2. Current extensive use of arable lands does not provide a serious hazard to surface waters quality, which was evidenced by lower than $50 mg \cdot dm^{-3}$ concentrations of nitrates, which in all analysed samples met the requirements of the Nitrate Directive.
3. High concentrations of trace elements were registered in the runoff water from catchments situated in the vicinity of city agglomerations. Due to their toxicity, the elements are most dangerous for living organisms. Their concentrations in waters from other catchments were very low, often below the quantification limit. It shows that in the areas under small anthropogenic pressure, it is possible to reduce considerably the frequency of heavy metal assessment.
4. The physicochemical parameters in the mountain and upland rivers of southern Poland most often deteriorating the use of surface waters intended for water supply for human consumption comprise mainly concentrations of manganese and/or iron. Their high content is connected with the high abundance in these elements of the Carpathian flysch rocks and brown leached soils and soil lessivés developed on them.
5. The requirements posed to natural fish habitats were not fulfilled in 11 out of 12 investigated catchments, mainly because of high nitrate concentrations. Even in the catchments with considerable afforestation rates, where the anthropopressure is slight, the conditions were unfavourable. It may be inferred, that normative values for nitrates are too strict, as confirmed by the results of research conducted under the framework of the State Water Monitoring, which only in several percent of cases allowed to declare waters as suitable for fish life and development.
6. In the catchments where soils are susceptible to water erosion, actions aimed at their reduction should be taken, usning anti erosion measures and construction of preliminary reservoirs, which in result would slow down silting up of planned small retention reservoirs and prolong their proper functioning.
7. Due to a considerable risk of water pollution, the reservoirs planned on the watercourses under strong anthropopressure, should be constructed as dry flood control reservoirs. However, this does not exclude the necessity to undertake activities aimed at eliminating the sources of

pollution in their catchments, which will allow to realise the environmental objectives stated in the Framework Water Directive.

8. In result of arable lands transformation into permanently turfed areas, concentrations of a majority of investigated chemical indices (including biogenic ones) decreased considerably in the water outflowing from a small agricultural catchment. The obtained results point to a beneficial effect of grassland and herbaceous vegetation on limiting chemical substance penetration from agricultural areas to surface waters, confirming the legitimacy of ecotones application as biogeochemical barriers.
9. Satisfying the requirements of the Framework Water Directive concerning the achievement and maintaining good water status requires a new approach in development of agricultural space, including a change in the management and use of catchments with strongly diverse landforms.
10. Small hydrological structures function as some kind of point regulators of oxygen in the flowing water, because they cause a decline during satiation, while during oxygen deficiency they significantly increase it content. Therefore they play an important role in the improvement of oxygen conditions in rivers, which intensifies water self-purification processes.
11. No significant correlation was found between the pool elevation and oxygen increase after water flowing through the hydraulic structures. On the other hand, it was noticed that the less water is saturated with oxygen before the backwaters, the greater and more significant is the impact of small hydraulic structures on the improvement of oxygen conditions in the river below damming.
12. At current technologies of sewage treatment and legislative requirements, modern treatment plants usually satisfy the requirements stated in the legal water permits, which however in many cases does not eliminate pollution process in the receiving waters.
13. For environmental reasons, legal water permits for sewage treatment plants should take into account in a greater extent the quantitative and qualitative state of the receiving water above the sewage discharge point, whereas the normative values referring to phosphorus and total nitrogen contents in treated sewage should be based on the admissible concentrations, not the percent of reduction of these pollutions.
14. If water inflowing to them is not strongly polluted, small and large artificial water reservoirs positively affect quality parameters in river water. In result of sedimentation, accumulation in bottom sediments and biological sorption, water salinity decreases and the biogenic substances concentrations diminish.
15. In result of conducted investigations it was stated, that the selected anthropogenic factors in diverse ways impact surface water quality in the upland and mountain catchments. High urbanisation of the catchment, intensive farming activities and to some extent also treated sewage worsen the quality status, but properly conducted transformation of the catchment man-

agement and water reservoirs, as well as hydraulic structures may improve water quality parameters.

References

Al-Shami S.A., Rawi Ch.S.M., Ahmad A.H., Hamid S.A., Nor S.A.M. 2011. Influence of agricultural, industrial, and anthropogenic stresses on the distribution and diversity of macro invertebrates in Juru River basin, Penang, Malaysia. Ecotoxicology and Environmental Safety, 74, 1195–1202 (in English).

Bakarat A., El Baghdadi M., Meddah R., Rais J., Nadem S., Afdali M. 2013. Evaluation of water quality in open channels flowing through Beni-Mellal City (Morocco). J. Water Land Dev., 19 (VII–XII), 3–11 (in English).

Bedla D., Misztal A. 2014. Zmienność chemizmu wód małych zbiorników wodnych o zróżnicowanej strukturze użytkowania terenów przyległych. Rocz. Ochr. Środ., 16, 421–439 (in Polish).

Bogdał A., Kanownik W., Wiśnios M. 2012a. Zmiany wartości i stężeń fizykochemicznych wskaźników jakościowych wód rzeki Prądnik-Białucha (Wyżyna Krakowsko-Częstochowska). Gaz, Woda i Tech. Sanit. 8, 358–361 (in Polish).

Bogdał A., Kowalik T., Kanownik W., Ostrowski K., Wiśnios M. 2012b. Ocena stanu fizykochemicznego wód opadowych i odpływających ze zlewni potoku Wolninka. Gaz, Woda i Tech. Sanit. 8, 362–365 (in Polish).

Bogdał A., Ostrowski K. 2008. Ocena przydatności wody potoku Rygliczanka do magazynowania w zbiorniku małej retencji. Gaz, Woda i Tech. Sanit., 9, 43–46 (in Polish).

Brzeziński R., Bonisławska M. 2010. Oddziaływanie wybranych budowli hydrotechnicznych na drożność i jakość wód rzeki Krąpiel. Gospodarka Wodna, 1/2010, 34–43 (in Polish).

Bulut V.N., Bayram A., Gundogdu A., Soylak M., Tufekci M. 2010. Assessment of water quality parameters in the stream Galyan, Trabzon, Turkey. Environ. Monit. Assess., 165, 1–13 (in English).

Burchard J., Dubaniewicz H. 1981. Współczynnik zanieczyszczenia jako miara kompleksowej oceny stopnia zanieczyszczenia wód powierzchniowych na przykładzie Pilicy i Bzury. Mat. IX Ogólnopol. Konf. Hydrograf., Łódź (in Polish).

Bus A., Mosiej J. 2013. Analiza przyczynowo-skutkowa wpływu zbiornika wstępnego Kupientyn na jakość wody w rzece Cetyni. Acta Sci. Pol., Formatio Circumiectus, 12 (2), 13–22 (in Polish).

Chełmicki W. 2001. Woda. Zasoby, degradacja, ochrona. PWN, Warszawa, ss. 305 (in Polish).

Chucki Sz., Staniszewski Z. 2012. Problemy światowego deficytu wody. Zesz. Nauk.– Inżynieria Lądowa i Wodna w Kształtowaniu Środowiska, 4, 59–68 (in Polish).

Cybulska A. 2012. deficytowa woda. Poradnik Gospodarski 07/08, 59–68 (in Polish).

Dojlido J. 1995. Chemia wód powierzchniowych. Wyd. Ekonomia i Środ., Białystok, ss. 342 (in Polish).

Duer I. 2005. Ochrona wód na obszarach wiejskich w świetle dobrej praktyki rolniczej. Post. Nauk Rol., 3 (315), 75–85 (in Polish).

Durkowski T., Korybut-Woroniecki T. 2009. Dynamika stężenia wybranych składników chemicznych w opadach atmosferycznych w zlewni jeziora Miedwie. Woda Środ. Obsz. Wiej., 9, 2 (26), 19–32 (in Polish).

Durkowski T., Wesołowski P. 2008. Kształtowanie się odpływu wody i zanieczyszczeń z małych zlewni rolniczych. Zesz. Prob. Nauk Rol., 528, 41–47 (in Polish).

Durkowski T., Wesołowski P., Królak B. 2006. Jakość wód gruntowych i powierzchniowych w otoczeniu zagród wiejskich w rejonie miejscowości Pyrzyce. Zesz. Prob. Nauk Rol., 512, 105–110 (in Polish).

Grzywna A. 2014. Chemiczne wskaźniki jakości wody w zlewni lasów Parczewskich. Inzynieria Ekologiczna, 36, 120–127 (in Polish).

Hachoł J., Krzemińska A. 2008. Wpływ regulacji rzeki Smortawy na przebieg procesów samooczyszczania na przykładzie wskaźników tlenowych. Infrastruktura i Ekologia Terenów Wiejskich, 9/2008, 207–216 (in Polish).

Hutchins M.G. 2012. What impact might mitigation of diffuse nitrate pollution have on river water quality in a rural catchment? Journal of Environmental Management, 109, 19–26 (in English).

Ilnicki P. 2014. Emission of nitro gen and phosphorus into rivers from agricultural land – selected controversial issues. J. Water Land Dev., 23 (X–XII), 31–39 (in English).

Jekatierynczuk-Rudczyk E., Zieliński P., Górniak A. 2006. Stopień degradacji rzeki wiejskiej w bezpośrednim sąsiedztwie Białegostoku. Woda-Środowisko-Obszary Wiejskie, 6, 2 (18), 143–153 (in Polish).

Juszkiewicz A., Bartynowska-Meus Z., Kawałek M., Meus M., Łaptaś A. 2006. Wpływ oczyszczalni ścieków na jakość wód dorzecza Rudawy. Aura, 6, 12–13 (in Polish).

Kanownik W., Kowalik T., Bogdał A., Ostrowski K., Rajda W. 2011. Jakość i walory użytkowe wody potoku Szczyrzawy. Zesz. Prob. Post. Nauk Rol. 561, 65–79 (in Polish).

Kanownik W., Rajda W. 2008. Źródła zanieczyszczenia wód powierzchniowych w zlewni potoku Sudół Dominikański. Acta Sci. Pol., Formatio Circumiectus, 7 (2), 3–14 (in Polish).

Kanownik W., Rajda W. 2009. Jakość wody w małych zlewniach w rejonie Krakowa objętych Programem Małej Retencji. Wiad. Mel. Łąk., 52, 1, 9–12 (in Polish).

Kanownik W., Rajda W. 2011. Wpływ oczyszczonych ścieków na jakość wód w odbiorniku. Gaz, Woda i Tech. Sanit., 10, 336–368 (in Polish).

Kiedrzyńska E., Urbaniak M., Kiedrzyński M., Skłodowski M., Zalewski M. 2012. Punktowe źródła zanieczyszczeń jako zagrożenie dla jakości wód Pilicy. Gaz, Woda i Tech. Sanit., 6, 254–256 (in Polish).

Kiryluk A., Leszczyński J., Łukowski A., Miłaszewski R., Piekutin J., Slemieniuk A., Skorbiłowicz E., Skorbiłowicz M., Szczykowska J., Wiater J., Żebranowicz J. 2014. Źródła zanieczyszczeń wód powierzchniowych i wybrane metody ich oczyszczania. Budownictwo i Inżynieria Środowiska, 5, 49–57 (in Polish).

Koc J. 1998. Wpływ intensywności użytkowania terenu na wielkość odpływu biogenów z obszarów rolniczych. Rocz. AR Pozn., Rolnictwo, 52, 2, 101–106 (in Polish).

Koc J., Duda M., Tucholski S. 2008. Znaczenie zbiornika retencyjnego dla ochrony jeziora przed spływami fosforu ze zlewni rolniczej. Acta Sci. Pol., Formatio Circumiectus, 7 (1), 13–24 (in Polish).

Koc J., Skonieczyk P. 2007. Role of retention reservoir in protecting a lake from biogenic substances running off from rural areas. Pol. J. Environ. Stud., 16 (2A), 292–296 (in English).

Kopacz M., Twardy S. 2006. Zmiany użytkowania ziemi z zlewni Górnego Dunajca w aspekcie wybranych parametrów jakościowych wód powierzchniowych. Woda-Srodowisko-Obszary Wiejskie, 6, 2 (18), 191–202 (in Polish).

Kopacz M., Twardy S., Kostuch M. 2007. Ładunek azotu pochodzącego ze źródeł rolniczych a zmiany użytkowania ziemi w dorzeczu górnej Wisły. Woda-Srodowisko-Obszary Wiejskie, 7, 2b (21), 87–97 (in Polish).

Kornijów R. 2011. Controversies around dam reservoirs: benefits, costs and future. Ecohydrology & Hydrobiology, 9, 2–4, 141–148 (in English).

Krasowska M., Banaszuk P. 2015. Drogi migracji biogenów w zlewni rolniczej. Inżynieria Ekologiczna, 43, 35–41 (in Polish).

Królak E., Korycińska M., Diadik K., Godziuk S. 2011. Czy lokalne oczyszczalnie ścieków wpływają na jakość wody ich odbiorników. Ochrona Środowiska i Zasobów Naturalnych, 48, 343–352 (in Polish).

Krzemińska A., Adynkiewicz-Piragas M., Kazimierska R. 2006. Ocena warunków terenowych dolnego odcinka rzeki Smortawy jako podstawa oceny samooczyszczania się wód w świetle wymogów Ramowej Dyrektywy Wodnej. Infrastruktura i Ekologia Terenów Wiejskich, 4/3/2006, 67–76 (in Polish).

Kuźniar A., Twardy S., Kowalczyk A. 2008. Przyczyny zmian stężenia związków azotu i fosforu w wodach powierzchniowych górnej zlewni Sanu (po przekrój Przemyślu) w latach 1990–2005. Woda-Srodowisko-Obszary Wiejskie, 8, 1 (22), 185–196 (in Polish).

Kwapuliński J., Wiechuła D., Loska K., Kmak-Kapusta D., Korczak K., Więckol-Ryk A. 2008. Samooczyszczanie się ekosystemu wodnego. Ekologia i Technika, 16 (2), 69–73 (in Polish).

Lai Y.C., Tu Y.T., Yang C. P. Surampalli R. Y., Kao C.M. 2013. Development of a water quality modeling system for river pollution index and suspended solid loading evaluation. Journal of Hydrology, 478, 89–101 (in English).

Liberacki D. 2004. Jakość wód powierzchniowych i gruntowych w małej zlewni leśnej. Acta Sci. Pol., ser. Form. Circ., 3 (1), 87–94 (in Polish).

Liberacki D., Stachowski P. 2008. Ocena małej retencji w Puszczy Zielonka i jej otulinie. Rocz. Ochr. Środ., 10, 657–678 (in Polish).

Liu X., Li G., Liu Z., Guo W., Gao N. 2010. Water pollution characteristics and assessment of lower reaches in Haihe River basin. Procedia Environmental Sciences, 2, 199–206 (in English).

Macrae M.L., English M.C., Schiff S.L., Stone M. 2007. Intra-annual variability in the contribution of tile drains to basin discharge and phosphorus export in a first order agricultural catchment. Agricultural Water Management, 92, 171–182 (in English).

Małecki Z., Gołębiak P. 2012. Zasoby wodne Polski i Świata. Zesz. Nauk.– Inżynieria Lądowa i Wodna w Kształtowaniu Środowiska, 7, 50–56 (in Polish).

Melcer B., Olejnik M. 2006. Wpływ wybranych czynników na zanieczyszczenie związkami biogennymi powierzchniowych wód płynących w zlewni Baryczy. Acta Sci. Pol., Form. Circ., 5 (2), 59–71 (in Polish).

Miatkowski Z., Smarzyńska K. 2014. Dynamika zmian stężenia związków azotu w wodach górnej Zgłowiączki w latach 1990–2011. Woda-Środowisko-Obszary Wiejskie, 14, 3 (47), 99–111 (in Polish).

Mioduszewski W. 2003. Mała retencja. Ochrona zasobów wodnych i środowiska naturalnego. Poradnik. Wyd. IMUZ, Falenty (in Polish).

Mioduszewski W. 2006. Woda na obszarach wiejskich. Woda-Środowisko-Obszary Wiejskie, 6, 1 (16), 277–295 (in Polish).

Misztal A., Kuczera M. 2008. The impact of land use on the water quality of foothill microcatchment areas. Ann. Wars. Agric. Univ. of Life Sci., Land Reclam., 40, 27–37 (in English).

Misztal A., Kuczera M. 2010. Impact of land use method in a catchments area on the dynamics of the nitrogen compounds in the outflowing water. Ecological Chemistry and Engineering, 17 (6), 642–649 (in English).

Monaghan R.M., Wilcock R.J., Smith L.C., Tikkisetty B. Thorrold B.S., Costall D. 2007. Linkages between land management activities and water quality in an intensively farmed catchment in southern New Zealand. Agriculture, Ecosystems and Environment, 118, 211–222 (in English).

Mosiej J., Komorowski H., Karczmarczyk A. Suska A. 2007. Wpływ zanieczyszczeń odprowadzanych z aglomeracji łódzkiej na jakość wody w rzece Ner i Warta. Acta Sci. Pol., Formatio Circumiectus, 6 (2), 19–30 (in Polish).

Mosiej J., Somorowski Cz. 2001. Aktualne problemy gospodarowania wodą w rolnictwie dla zrównoważonego rozwoju obszarów wiejskich. Wiad. Mel. i Łąk., 1, 2–7 (in Polish).

Mouri G., Shinoda S., Oki T. 2012. Assessing environmental improvement options from a water quality perspective for an urbane rural catchment. Environmental Modelling & Software, 32, 16–26 (in English).

Mrozik K., Przybyła Cz. 2013. Mała retencja w planowaniu przestrzennym. Wyd. PRODRUK, Poznań, ss. 216 (in Polish).

Murat-Błażejewska S., Kujawa J., Sojka M. 2003. Wpływ lasów i użytków zielonych na ochronę wód powierzchniowych przed eutrofizacją. Zesz. Nauk. AR w Krak., Inż. Środ., 24, 337–345 (in Polish).

Niczyporuk A., Wiater J. 2006. The influence of basin use of Chwiszcza and Perebel river on seasonal quality of discharge water. Pol. J. Environ. Stud., 15 (5A), 397–400 (in English).

Olszewska B., Krzemińska A. 2008. Jakość wód rzeki Jeziorki w latach 1995–2003. Zesz. Prob. Nauk Rol., 528, 105–114 (in Polish).

Orzepowski W., Paruch A.M. Pulikowski K., Kowalczyk T., Pokładek R. 2014. Quantitative and qualitative assessment variable climatic conditions of Silesian Lowlands (Southwest Poland). Agricultural Water Management, 138, 45–54 (in English).

Ostrowski K., Bogdał A. 2006. Ocena zasobów wód odpływających z wybranych małych zlewni rolniczych Pogórza Wadowickiego. Woda-Środowisko-Obszary Wiejskie, 6, 2 (18), 281–292 (in Polish).

Ostrowski K., Bogdał A. 2007. Wartości wybranych cech fizyko-chemicznych wody opadowej i odpływającej z mikrozlewni o osadniczo-rolniczo-hodowlanym użytkowaniu. Zesz. Probl. Post. Nauk Rol., 519, 233–244 (in Polish).

Ostrowski K., Policht A., Rajda W., Bogdał A. 2008. Zmiany przewodności elektrolitycznej i stężeń biogenów w wodzie z biegiem cieku odwadniającego małą zlewnię rolniczą. Zesz. Probl. Post. Nauk Roln., 528, 123–131 (in Polish).

Ostrowski K., Rajda W., Kowalik T., Kanownik W., Bogdał A. 2011. Hydrochemiczne uwarunkowania realizacji programu małej retencji na terenach górskich i podgórskich. Post. Nauk Rol. 1, 91–98 (in Polish).

Podedworna M., Marciniewicz M. 2004. Eutrofizacja wód. Gaz, Woda i Technika Sanitarna, 7–8, 275–278, 2004 (in Polish).

Policht–Latawiec A., Kanownik W., Łukasik D. 2013. Wpływ zanieczyszczeń punktowych na jakość wody rzeki San. Infrastruktura i Ekologia Terenów Wiejskich, 1/ IV, 253–269 (in Polish).

Policht-Latawiec A., Kanownik W., Rajda W. 2011. Biogenne i tlenowe wskaźniki jakości wody dopływającej i odpływającej z wybranych zbiorników wodnych. Gaz, Woda i Tech. Sanit. 10, 394–396 (in Polish).

Policht-Latawiec A., Kapica A. 2013. Influence of Hard Coal Mine on Water Quality in the Vistula River. Rocz. Ochr. Środ., 15, 2640–2651 (in Polish).

Program małej retencji województwa małopolskiego. 2004. Załącznik nr 1 do Uchwały nr XXV/344/04 Sejmiku Województwa Małopolskiego z dnia 25 października 2004 r. (in Polish).

Przybyła Cz. Kozdrój P., Sojka M. 2014a. Ocena jakości wód w lateralnych zbiornikach Jutrosin i Pakosław w pierwszych latach funkcjonowania. Inżynieria Ekologiczna, 39, 123–135 (in Polish).

Przybyła Cz., Kozdrój P., Sojka M. 2014b. Wykorzystanie wielowymiarowych metod statystycznych w analizie stanu fizykochemicznego wód w systemie rzeka – zbiornik retencyjny na przykładzie zbiorników retencyjnych Pakosław i Jutrosin położonych z zlewni rzeki Orli. Rocz. Ochr. Środ., 17, 1125–1141 (in Polish).

Przybyła Cz., Zbierska A., Dwornikowska Ż. 2011. Ocena zmian jakości wody w wybranych jeziorach Pojezierza Poznańskiego w latach 2004–2009. Rocz. Ochr. Środ., 13, 723–746 (in Polish).

Pulikowski K. 2004. Zanieczyszczenia obszarowe w małych zlewniach rolniczych. Zesz. Nauk. AR Wrocław, Rozprawy, 479, 1–137 (in Polish).

Pulikowski K., Hus T., Kostrzewa S., Paluch J., Pęczkowski G. 2008. Zawartość azotu i fosforu w wodach odpływających z małych zlewni użytkowanych rolniczo. Zesz. Prob. Post. Nauk Rol., 528, 157–164 (in Polish).

Radecki-Pawlik A., Kapusta A. 2006. Mała retencja i jej znaczenie. Aura, 3, 32–33 (in Polish).

Rajda W. 2005. Woda w zagospodarowaniu przestrzennym obszarów wiejskich. Post. Nauk Rol., 3 (315), 33–42 (in Polish).

Rajda W., Kanownik W. 2005. Wpływ czynników antropogenicznych na jakość wody potoku na terenie podmiejskim i zurbanizowanym. Wiad. Mel. Łąk., 4, 176–180 (in Polish).

Rajda W., Natkaniec J. 2001. The impact of select forms of antropopression on quality of surface waters. Ann. Wars. Agric. Univ. of Life Sci., Land Reclam., 31, 65–74 (in English).

Rajda W., Natkaniec J. 2006. The anthropogenic factors and water quality runoff from mountain-foot waterscheds. W: Materiały Międzyn. Konf. Nauk., Krajinné Inžinierstvo v Novom Tisicroči. Slovenska Poľnohospodárska Universita v Nitre, 132–139 (in English).

Rossa L., Sikorski M. 2006. Odpływy wybranych substancji z obszarów zabudowy wiejskiej. Woda-Środowisko-Obszary Wiejskie, 6, 1 (16), 335–347 (in Polish).

Rozporządzenie Ministra Ochrony Środowiska, Zasobów Naturalnych i Leśnictwa z dnia 5 listopada 1991 r. w sprawie klasyfikacji wód oraz warunków, jakim powinny odpowiadać ścieki wprowadzane do wód lub ziemi, Dz. U. Nr 116, poz. 503 (in Polish) [1991].

Rozporządzenie Ministra Środowiska Ministra Środowiska z dnia 4 października 2002 r. w sprawie wymagań, jakim powinny odpowiadać wody śródlądowe będące środowiskiem życia ryb w warunkach naturalnych, Dz. U. Nr 176, poz. 1455 (in Polish) [2002a].

Rozporządzenie Ministra Środowiska z dnia 27 listopada 2002 r. w sprawie wymagań jakim powinny odpowiadać wody powierzchniowe wykorzystywane do zaopatrzenia ludności w wodę przeznaczoną do spożycia, Dz. U. Nr 204, poz. 1728 (in Polish) [2002b].

Rozporządzenie Ministra Środowiska z dnia 23 grudnia 2002 r. w sprawie kryteriów wyznaczania wód wrażliwych na zanieczyszczenia związkami azotu ze źródeł rolniczych, Dz. U. Nr 241, poz. 2093 (in Polish) [2002c].

Rozporządzenie Ministra Środowiska z dnia 11 lutego 2004 r. w sprawie klasyfikacji dla prezentowania stanu wód powierzchniowych i podziemnych, sposobu prowadzenia monitoringu oraz sposobu interpretacji wyników i prezentacji stanu tych wód, Dz. U. Nr 32, poz. 284 (in Polish) [2004].

Rozporządzenie Ministra Środowiska z dnia 20 sierpnia 2008 r. w sprawie sposobu klasyfikacji stanu jednolitych części wód powierzchniowych, Dz. U. Nr 162, poz. 1008 (in Polish) [2008].

Rozporządzenie Ministra Środowiska z dnia 9 listopada 2011 r. w sprawie sposobu klasyfikacji stanu jednolitych części wód powierzchniowych oraz środowiskowych norm jakości dla substancji priorytetowych, Dz. U. Nr 258, poz. 1550 (in Polish) [2011].

Rozporządzenie Ministra Środowiska z dnia 22 października 2014 roku w sprawie sposobu klasyfikacji stanu jednolitych części wód powierzchniowych oraz środowiskowych norm jakości dla substancji priorytetowych, Dz. U. z 2014 r., poz. 1482 (in Polish) [2014a].

Rozporządzenie Ministra Środowiska z dnia 18 listopada 2014 roku w sprawie warunków jakie należy spełnić przy wprowadzaniu ścieków do wód lub do ziemi oraz w sprawie substancji szczególnie szkodliwych dla środowiska wodnego, Dz. U. z 2014 r., poz. 1800 (in Polish) [2014b].

Rozporządzenie Ministra Zdrowia z dnia 16 października 2002 r. w sprawie wymagań, jakim powinna odpowiadać woda w kąpieliskach, Dz. U. Nr 183, poz. 1530 (in Polish) [2002d].

Skorbiłowicz A., Skorbiłowicz E., Dzienis L. 2003. Oddziaływanie oczyszczalni ścieków na chemizm wód wybranych rzek zlewni górnej Narwi. Zesz. Nauk. PB, Inż. Środ., 16, 2, 171–174 (in Polish).

Skorbiłowicz M. 2007. Identification and evaluation of pollution sources influence on quality of river Orlanka, NE Poland. Pol. J. Environ. Stud., 16 (2A), 304–310 (in English).

Solovey T. 2008. Ocena potencjalnej eutrofizacji wód płynących w zlewni środkowej Wisły. Woda-Środowisko-Obszary Wiejskie, 8, 1 (22), 323–336 (in Polish).

Suchowolec T., Górniak A. 2006. Sezonowość jakości wody małych zbiorników retencyjnych w krajobrazie rolniczym Podlasia. Woda-Środowisko-Obszary wiejskie, 6, 2 (18), 347–358 (in Polish).

Theodoropoulos Ch., Iliopoulou-Georgudaki J. 2010. Response of biota to land use changes and water quality degradation in two medium-sized river basins in southwestern Greece. Ecological Indicators, 10, 1231–1238 (in English).

Twardy S., Jaguś A. 2001. Wpływ składowiska odpadów komunalnych na jakość wód potoku górskiego. Probl. Zagosp. Ziem Gór., 47, 43–53 (in Polish).

Wiatkowski M. 2006. Charakterystyka warunków hydrochemicznych w przekroju planowanego Zbiornika Kluczborskiego. Przegląd Nauk., Inż. i Kształt. Środ., XV, 2 (34), 189–198 (in Polish).

Wiatkowski M. 2010. Ocena jakości wody zbiornika Komorów na potoku Milówka. Infrastruktura i Ekologia Terenów Wiejskich, 8/2/2010, 51–64 (in Polish).

Wiatkowski M. 2013. Wstępne wyniki badań jakości wody małego zbiornika Michalice na Widawie. Inżynieria Ekologiczna, 35, 117–125 (in Polish).

Wiatkowski M. 2015. Problemy gospodarki wodnej zbiornika Młyny na rzece Julianpolanka. Acta Sci. Pol., Formatio Circumiectus, 14 (3), 191–203 (in Polish).

Wiatkowski M., Rosik-Dulewska Cz. 2011. Problemy gospodarki wodnej w zlewni zbiornika Włodzienin na rzece Troi w aspekcie założonych dla niego funkcji. Zesz. Prob. Nauk Rol., 564, 301–309 (in Polish).

Wiatkowski M., Rosik-Dulewska Cz., Gruss Ł. 2012. Profil zmian wskaźników jakości wody w rzece Stobrawie. Infrastruktura i Ekologia Terenów Wiejskich, 3/IV/2012, 21–35 (in Polish).

Wiatkowski M., Rosik-Dulewska Cz., Wiatkowska B. 2010. Charakterystyka stanu użytkowania małego zbiornika zaporowego Nowaki na Korzkwi. Rocz. Ochr. Środ., 12, 351–364 (in Polish).

Żmuda R., Sasik J., Szewrański Sz. 2001. Odpływ wybranych składników materii ze zlewni rolniczej Wzgórz Trzebnickich. Zesz. Nauk. AR w Krak., Inż. Środ., 21, 41–47 (in Polish).

Żmuda R., Szewrański Sz. 2008. Wymywanie fosforu z gleb lessowych poddanych procesowi erozji wodnej. Zesz. Prob. Nauk Rol., 528, 279–284 (in Polish).

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