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# Appendix 3

## Summary of professional accomplishments

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## I. Education and degrees

In 1986, I graduated XIV High School of the name of „Polonia Belgijska" in Wrocław. The same year I started full-time M.Sc. studies at the Faculty of Sanitary Engineering of the Wrocław University of Science and Technology. In 1992, I completed studies in the field of "Water supply and disposal of sewage and solid-wastes" with an excellent degree, defended M.Sc. thesis "Treatment of groundwater contaminated with ammonia nitrogen, iron and manganese", obtaining with honors Masters of Science Degree in Sanitary Engineering.

I worked on my Ph.D. dissertation at the Faculty of Environmental Engineering (initially as the Faculty of Sanitary Engineering) of the Wrocław University of Science and Technology under the supervision of Prof. Wojciech Adamski. The Ph.D. dissertation "Kinetics of the adsorption-biodegradation process on granular activated carbon beds for water treatment" implemented as a part of the promotion grant, I defended with honors in 2000. The dissertation was reviewed by Prof. Apolinary L. Kowal and Prof. Jerzy Choma.

## II. Information on previous employment

In 1992, I started work as an assistant at the Faculty of Sanitary Engineering at the Wroclaw University of Science and Technology, which is continuously the basic place of my employment until today. In 2001, I was promoted to the position of the scientific and teaching adjunct, which I have held till now. I was the member of the Institute of Environmental Protection Engineering Council (2003-2005), Faculty of Environmental Engineering Council (2005-2008) and Faculty's Election Commission (2005-2008). In the years 2008-2009, I managed the Didactic Group of Water, Sewage and Solid-Wastes Technology.

Since 2014, I have been also working for Municipal Water and Sewage Company in Wrocław (MPWiK S.A.) within the Center of New Technologies, which is the research and development unit of the company, i.a. responsible for conducting of research projects.

## III. Scientific achievement being the basis of the habilitation procedure

Title:

*Parameters of anion exchange on powdered magnetic adsorbents as a control tool for natural organic matter removal from water*

Author:

Marek Mołczan

Publishing House:

Publishing House of Wroclaw University of Science and Technology, Wroclaw 2019

Publishing reviewers:

Prof. Katarzyna Majewska-Nowak

Prof. Zbigniew Heidrich

Work description:

Anion exchange on powdered magnetic adsorbents represents a significant technological advance in natural organic matter (NOM) removal from water, facilitated by:

- use of fine-grained adsorbent with high ion exchange rate (including NOM macroanions exchange),
- multiple adsorbent application due to magnetic separation and on-site chemical regeneration system,
- continuous process operation,
- adsorption operation at the beginning of a treatment train, which improves performance of downstream processes.

An anion exchange control method has been proposed in this study, based on the concept of a set of parameters influencing process performance in relation to steady-state conditions. The applicability of the proposed solution was validated for two types of reactors: dual-stage (DS) and single-stage (also high-rate, HR) reactor. The objectives of the study included:

- definition of the key process control parameters,
- determination of the parameter applicability for process operation.

General criteria for parameter usability were defined, which led to identification of two groups of parameters, i.e. primary and secondary parameters. The primary parameters included:

- adsorbent concentration (dose) in the reactor ($D_{ż}$),
- contact time between adsorbent and treated water ($t_p$),
- regeneration ratio ($R$) or regeneration flowrate ($Q_{żw}$),
- adsorbent dispersion in the reactor,
- regenerated (fresh) adsorbent concentration ($D_{żr}$),
- adsorbent concentration in the recirculation stream ($D_{żw}$).

Primary parameters directly influence the process, while the secondary parameters help create a complete picture of the process to deepen its understanding, identify interdependencies between the parameters and evaluate applicability of the primary parameters for achieving technological objectives. The secondary parameters were identified as follows:

- adsorbent bed volume ($BV$) or adsorbent bed volume treatment rate ($BVTR$),
- effective (or equivalent) adsorbent dose ($ERD$),
- adsorbent age (equivalent to solids residence time) ($t_{pż}$),
- indicators determined based on kinetic curve analysis (reaction rate, efficient adsorbent dose, range of process applicability, mutual "substitutability" of adsorbent dose and contact time).

The above set of parameters, together with their proven mathematical interrelations, provides a powerful tool to describe the steady-state or the steady-state range characteristic for a chosen application. In addition, it allows for transitioning between different steady-states as well as for all the necessary data determination.

A broader perspective of process application was also described in terms of:

- procedures (including adsorbent regeneration and process control),
- factors affecting process operation (objective, i.e. solution properties, their variability; subjective, i.e. reactor mixing conditions),
- methods of the process optimization.

A particular focus was put on regeneration, including various regeneration agents, regeneration procedures and methods of waste solutions disposal. A number of NOM properties affecting the anion exchange was assessed (function groups, molecular weight, charge density, specific UV absorbance), as well as solution characteristics (pH, temperature, ionic strength) and competitive anion interactions. The analysis of adsorbent mixing

conditions allowed for appreciation of the importance not only of the mixing intensity aspect but also of the manner of mixing as the motion caused by mechanical, hydraulic or magnetic stimulation.

Finally, the monograph covers a description of MIEX®DOC resin, characteristics of selected powdered magnetic adsorbents that could serve as the MIEX®DOC alternative, overview of the research methods and the reactors construction, discussion about the process integration with water treatment trains and assessments of the development prospects.

The original work covered by the monograph includes:

1. The comprehensive and structured overview of the process research methods.
   The monograph focuses on the factors critical for the methodological correctness and the comparability between the results of various studies. The methodological elements that govern the correctness and equivalence of determined parameters (the guide rules for water and adsorbent preparation, for test performance and result interpretation, for adsorbent dose measurement, including the requirement to acknowledge its swelling) were emphasized. Without them, the proposed process control system would be inconsistent and subject to the risk of generating misleading messages.
2. The compilation of Polish terminology relevant to the process.
   The monograph develops a system of concepts supporting characteristics of the process. To this end, it presents a well-established and available in the literature system of concepts and definitions in a structured fashion, while proposing new concepts to fill gaps in the method description. The new concepts and definitions include the name of the process (anion exchange on magnetic powdered adsorbents), the main volume flow rates of the adsorbent in the settled form ($Q_{ż}, Q_{żw}, Q_{żr}$) and aqueous suspension ($Q_{sżw}, Q_{sżr}, Q_{sżp}$), the time needed to achieve the adsorption equilibrium ($t_R$). The proposed Polish equivalents include: the equivalent resin dose, resin age, regeneration ratio, single-loading test, single-stage and dual-stage reactor.
3. Identification of the parameter groups (primary and secondary parameters) with different functions in the process control system.
   This differentiation is of primary importance in the proposed method of the process control via its parameters. The operator is provided with a full range of tools to influence the process directly (primary parameters) bearing in mind that they will not be helpful in the assessment of the process state or determination of necessary changes of this state. This is the purpose of the secondary parameters.
4. Demonstration of the key relations between the process parameters and in particular between the primary and secondary parameters.
   Usability of the control system was established through the precise definition of the individual parameters roles and their interrelations. Thus, messages generated by the parameter values of the interpretive meaning can be converted into the process settings. In reverse, the applied primary parameter values may be converted into the indicators that enable prediction of changes in the process outcomes. We could point to the following correlations as examples:

$$BV = \frac{1}{R \cdot D_{ż}} \tag{1}$$

$$ERD = \frac{1}{BV} \tag{2}$$

$$t_p \cdot D_{\dot{z}} = t_{p\dot{z}} \cdot ERD \quad (3)$$

which are related to the process effectiveness. Both the product value ($t_p \cdot D_{\dot{z}}$) and the value of the equivalent dose ($ERD$), and thus the reverse of the bed volume ($1/BV$), are proportional to the process effectiveness, which was confirmed both in theory and in practice. For the resin age ($t_{p\dot{z}}$), the inverse correlation should be pointed out, because a small age value correlates with frequent regeneration and thus greater effectiveness of the adsorbent.

5. Definition of the process steady-state conditions.
   The monograph describes three levels of the steady state conditions, the most important of which is related to the process equilibrium associated with the interrelations between the purified water flow and adsorbent circulation (equilibrium between adsorption and regeneration streams), described by the secondary parameters but implemented using the primary parameters. The process equilibrium control consists in maintaining the assumed steady-state conditions on the one hand and in carrying out the controlled changes of one steady-state into another, on the other.
6. Demonstration of the interpretative consistency of the proposed process description, independently of the reactor design (DS or HR type).
   The monograph presents the fundamental picture of the process based on contact between the two streams: water and adsorbent with the adsorption capacity being reproduced at a fixed rate by regeneration. This approach refers directly to the process mechanism, thus it does not differentiate the method description between different reactor systems.
7. The attention paid to the role of the ion-exchange reaction kinetics in the process description and its exploitation.
   Almost all the process analyses performed to date are based on evaluation of the adsorption equilibria and adsorption capacity, neglecting the aspect of kinetics and reaction rate. The paper demonstrated that analysis of the kinetic curves of adsorption provided information unavailable from the reactor operation monitoring, thus supplementing the operational data. This information is of strategic importance as it allows optimization of technological variants of the process. Close associations between kinetic curve parameters and the reactor operation is an important area for future research.
8. Indication of feasibility to utilize the external magnetic field forces in the dispersion of magnetic adsorbent in the reactor.
   Application of the external magnetic field was demonstrated not to affect the adsorption rate. However, the procedure may exert a positive effect by reducing adsorbent losses and allowing greater control over its distribution in the reactor, especially under variable or high hydraulic loading rates.
9. Structuring of procedures and magnetic regeneration conditions of the anion-exchange resins.
   The extensive chapter 7.10 discusses all important aspects of the capacity recovery for the magnetic anion exchange adsorbent. Both applied and potential solutions, such as the original concept of continuous regeneration, were discussed. No other such a complete example of regeneration by the anion exchange process on magnetic powdered adsorbents is available in the literature.

## IV. Description of other scientific achievements

My scientific achievements (affiliation of (Wrocław University of Science and Technology + MPWiK S.A.) were marked in brackets) include a total number of 99 (84+15) items, including: 1 (1+0) individual monograph, 8 (6+2) chapters in books or monographs, 47 (46+1) articles (including 21 (20+1) indexed in Web of Science), 13 (12+1) with IF), 23 (21+2) conference papers (oral presentations) or posters (including 3 (3+0) indexed in Web of Science and 14 (12+2) published alongside as articles or chapters in books or monographs), 3 (3+0) book reviews published in journal and 31 (19+12) reports from research works (collections: SPR, PRE (Ph.D. dissertation), DC and CNT). Furthermore, my achievements include 5 (2+3) conference presentations (Appendix 4, items: L7-L11) and 8 (4+4) expert analyses or opinions (Appendix 4, items: M1-M8), which are out of library collections of Wrocław University of Science and Technology and MPWiK S.A.

In Appendix 4, entitled „*List of published scientific papers and information about the didactic achievements, scientific cooperation and promoting of science*", there is given a bibliographic description of my academic and scientific work which include a total number of 99 items (25 individual and 74 teamworks) and 13 items out of library collections (10 individual and 3 teamworks).

In the period before obtaining the Ph.D. degree (1992–2000), I collected a total of 19 works (12 individual and 7 teamworks). Of these, I published a total of 10 works, including:

- 6 articles in scientific journals (including 2 conference presentations),
- 1 conference paper,
- 3 book reviews published in journal.

After obtaining Ph.D. degree (2000–2019), I have assembled in my output a total number of 80 works (including 13 individual and 67 teamwork). I published 58 of them, including:

- 1 monograph (being the scientific achievement mentioned in point III),
- 8 chapters in books or monographs,
- 13 articles in IF journals, including 1 individual,
- 28 articles in scientific journals without IF, including 7 individual (out of a total number of 28 articles without IF, 25 (including 6 individual) were published in scored journals),
- 3 conference papers indexed in the Web of Science,
- 5 other conference papers, including 1 individual.

In Table 1 there is presented the structure and numerical summary of my output divided into periods: before and after obtaining the Ph.D. degree. Table 2 includes supplementary data of items out of library collections.

The total point achievements of my publications amounts to 484 points, and after deducting share of co-authors work 228,05 points (including respectively 222 and 79,3 points for IF journals). The total IF amounts to 12,274, including 4,009 of my own contribution. Total points and IF achievements have been obtained after obtaining the Ph.D degree.

Bibliometric indicators (number of works, citations, h-index) of my scientific output, depending on the base, amount to:

- Web of Science: number of works: 24, citations: 81, h-index: 5.
- Scopus: number of works: 18, citations: 84, h-index: 5.
- Google Scholar: number of works: 44, citations: 292, h-index: 9.

I have discussed below my interests and scientific achievements with references to the list of scientific achievements – given in Appendix 4.

Table 1. A synthetic overview of research output: individual (Ind.) and co-authored (Co-a.)

| Type of work | Prior to the Award of Doctoral Degree | | | After the Award of Doctoral Degree | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| | Ind. | Co-a. | Total | Ind. | Co-a. | Total | Ind. | Co-a. | Total |
| Monographs | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 |
| Chapters[1)] | 0 | 0 | 0 | 0 | 8 | 8 | 0 | 8 | 8 |
| Articles with IF | 0 | 0 | 0 | 1 | 12 | 13 | 1 | 12 | 13 |
| WoS art. without IF[2)] | 0 | 0 | 0 | 4 | 4 | 8 | 4 | 4 | 8 |
| Articles without IF[3)] | 3 | 3 | 6 | 3 | 17 | 20 | 6 | 20 | 26 |
| WoS conf. papers | 0 | 0 | 0 | 0 | 3 | 3 | 0 | 3 | 3 |
| Other conf. papers[4)] | 1 | 0 | 1 | 1 | 4 | 5 | 2 | 4 | 6 |
| Reviews in journal[5)] | 3 | 0 | 3 | 0 | 0 | 0 | 3 | 0 | 3 |
| Reports SPR/PRE[6)] | 5 | 4 | 9 | 0 | 10 | 10 | 5 | 14 | 19 |
| MPWiK S.A. reports[7)] | 0 | 0 | 0 | 3 | 9 | 12 | 3 | 9 | 12 |
| Total | 12 | 7 | 19 | 13 | 67 | 80 | 25 | 74 | 99 |

[1)] Chapters in books or monographs
[2)] Articles without IF but indexed by Web of Science (WoS)
[3)] Other articles without IF and not indexed by Web of Science (WoS)
[4)] Other conference papers, not published as book or monograph chapter or Web of Science conference paper
[5)] Book reviews published in journal
[6)] Reports affiliated with Wrocław University of Science and Technology
[7)] Reports affiliated with MPWiK S.A.

Table 2. An overview of research output not included in library collections (after obtaining Ph.D. degree): individual (Ind.) and co-authored (Co-a.)

| Type of work | Wrocław Univ. of Sci. And Technol. | | | MPWiK S.A. | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| | Ind. | Co-a. | Total | Ind. | Co-a. | Total | Ind. | Co-a. | Total |
| Expert analyses or opinions | 3 | 1 | 4 | 3 | 1 | 4 | 6 | 2 | 8 |
| Conference presentations | 2 | 0 | 2 | 2 | 1 | 3 | 4 | 1 | 5 |
| Total | 5 | 1 | 6 | 5 | 2 | 7 | 10 | 3 | 13 |

## Timespan before obtaining Ph.D. degree (1992–2000)

In the timespan before obtaining the Ph.D., my research interests covered the following topics:

1. employment of biological methods in the processes of groundwater and surface water treatment,
2. employment of adsorption methods in water treatment processes,
3. the significance of organic matter removal for water disinfection.

**Ad. 1.** My first research projects focused on the control of processes employing biological activity to stimulate water treatment phenomena. The first process in this group was dry

filtration used for iron and manganese removal from the ammonia-rich groundwater. The research results were summarized in the article (Appendix 4, item E9) and presented during the conference (conference paper L1). The second process studied was biofiltration, where microbial activity facilitates the organic matter removal by the granular activated carbon (GAC) beds. This subject matter formed the basis for the research project (report J3) and the Ph.D. thesis (J9), which I carried out within the framework of the supervisor grant. As part of this work, I put forward the theses supporting selection of the adsorbent-biomass carrier and optimization of the process conditions, determined the practical efficiency of biodegradation and created the process model that combined the effects of adsorption and biodegradation. The reports (J2, J4-J6) and articles (E12, E13) documented the results of my work.

**Ad. 2.** My interest in the adsorption of organic substances from water developed from the research projects carried out for my doctoral dissertation (J9). Analysis of the adsorption as a stand-alone process formed the basis to describe the biological filtration process (reports J2-J6, articles E12, E13).

**Ad. 3.** At the turn of the 20th and 21st centuries, much attention was paid to the formation of disinfection by-products (DBPs), mainly trihalomethanes (THMs). The research indicated the need to remove the DBPs precursors, reduce the disinfectant dose (mostly chlorine) or replace it with a disinfectant presenting less risk to health (e.g., chlorine dioxide). I have addressed this topic, which resulted in the proposal of correlation between chlorine dioxide demand and the organic matter content in water. Consequently, it became feasible to set the requirements for the organic matter removal from the water before its disinfection. The research results were presented at the conference (conference paper E14) and in the article (E14).

## Timespan after obtaining Ph.D. degree (2000–2019)

Following my Ph.D., I continued the research into the formerly selected topics (especially 2-3) but also into the new areas, including (4-10):

4. directions for the development of water treatment technologies,
5. characteristics of the natural organic matter (NOM) in water,
6. water treatment by coagulation,
7. soil protection and reclamation,
8. organic matter removal from water by the ion exchange adsorption,
9. water purification by membrane separation,
10. interdependencies between processes that build the water treatment train and the operational assessment of the entire water purification system.

**Ad. 1.** In the period 2001-2006, I described the principles of adsorption-biodegradation process modeling, including conditions of the biomass self-reproduction and the main concepts of the concentration profile in the boundary layer (article E23). Further, I characterized the application criteria of the process as mentioned above (related both to the biodegradation kinetics and the process economics) and the main parameters of the method (conference presentation L7), which ended the period of my interest in this topic. A few years later, the article analyzing conditions of the stability (including biological stability) of water introduced into the water supply network (article A6) referred to this subject.

**Ad. 2.** In my research into the adsorption, I was particularly interested in the innovative adsorbents application. I studied the NOM adsorption using the experimental AGL adsorbent

with spherical grains. I indicated its original features such as the deep adsorption ability (article E15). The same product was subject to the studies aimed at health evaluation of drinking water quality, which, among others, addressed the possibility of its secondary contamination with genotoxic substances at the advanced stage of GAC bed exploitation (conference paper L3). The pilot studies of the NOM adsorption were documented in the articles A11, E7 and E8. In the publication A8, the influence of ozonation on the effectiveness of organic matter adsorption in the activated carbon bed was investigated. An increase in effectiveness even by a few percent has been determined to extend the operation cycle of the GAC bed by 1/3.

**Ad. 3.** I have always conducted my research into the water disinfection in connection with the issue of NOM removal from water. My work was mainly related to the assessment of the influence of the method and conditions for NOM removal on the disinfectant dose and DBPs formation (articles A7, A13, E45; report J16). The article A7 demonstrated that MIEX®Gold protected the tested water against THMs formation better than MIEX®DOC resin, despite the less efficient dissolved organic carbon (DOC) removal. The publication A13 confirmed that the disinfectant doses ($Cl_2$, $ClO_2$) depended almost exclusively on the DOC content in the disinfected water.

**Ad. 4.** A particular undertaking was the technological diagnosis of the Polish water supply industry carried out under my supervision in the period 2004-2005, in which a total of 215 companies participated. The results indicated an urgent need for implementing the processes capable of effective organic matter removal as well as safe oxidation methods and were published as a series of three articles in the period 2007-2008 (E32-E34).

**Ad. 5.** Significantly, the removal of organic substances from water is associated with the NOM properties. The two of my review articles (articles E19 and A8) analyzed the available methods and the indicators of NOM characteristics. Some of them, I have employed in the subsequent research projects (e.g., A1, E1, E2, E8, E18, E24, E25, E30, E43). The indicators of particular importance for my research included the NOM (total and dissolved organic carbon – TOC and DOC) content, absorbance at 254 nm ($UV_{254}$), specific UV absorbance (SUVA), color and specific color absorbance (SCOA), absorbance slope index (ASI) and molecular weight distribution by size exclusion chromatography (SEC). Also the Ph.D. thesis that I am an auxiliary supervisor of addresses the issues mentioned above (Appendix 4, point III K).

**Ad. 6.** Many of my articles discussed various aspects of coagulation application, including comparison of the effects of aluminium salts and pre-hydrolysed polyaluminium chlorides (articles A36, E37), coagulant selection and an estimate of their application costs (articles A10, A12, E6, E42), integration of the coagulation process with other processes of the treatment train (articles E25, E27, E38) and management of the coagulation process with the use of pilot studies (conference paper L6). The common thesis of these articles is to indicate the need for an individualized selection of the coagulant and conditions of its use for each application.

**Ad. 7.** In the period 2012-2014, in cooperation with the Wrocław University of Environmental and Life Sciences, I performed analyses of the organic matter content in water extracts from metal-contaminated soils, which was documented in the publications (articles A9, E40, E41).

**Ad. 8.** Removal of NOM by anion exchange adsorption with the use of magnetic powdered adsorbents has been the central area of my interests since 2005 and covered several specific topics:

- the process characteristics and its applications (articles E20, E21, E26);

- implementations and modifications of the research methods in the batch and continuous flow studies as well as jar and pilot tests, single- and multi-stage, including both experimental and analytical aspects (articles E16, E17, E22, E29, E35);
- evaluation of the kinetics and statics of adsorption, including the development of the kinetics model with an assessment of the reaction rate of NOM removal and the improvement of statics studies to assess the adsorbent capacity (articles A2, E1, E18, E22, E28, E29);
- verification of the influence of process factors, including the solution properties (DOC, color, SUVA, NOM particle size, anions content) and operating conditions (method and intensity of mixing) on the process effectiveness (articles A4, E3, E17, E24, E27, E28, E30, E31, E35, E39);
- evaluation of the separation specificity of magnetic adsorbent types (article A7);
- the regeneration optimization (performed within research partially presented in article E17);
- validation of the process position in the treatment train with the evaluation of interactions with other processes (coagulation, GAC adsorption, membrane separation, oxidation) (articles A1, A4, E1, E2, E25, E27, E28, E30, E38).

The most significant achievements of these articles include building the process kinetics model together with its developed interpretative structure (articles E18, E22, E28, E29), illustrating the importance of the reaction rate against adsorbent capacity as diverse process control tools (articles E18, E28, E39), evaluation of the role of SUVA index in the process (articles E18, E30, E35), acknowledgment of the role of the anionite swelling in the resin dose control (article A3).

The research described in the publications mentioned above provided the basis for a complex characterization of the anion exchange process on magnetic powdered adsorbents included in the habilitation thesis.

**Ad. 9-10.** Integration of the membrane separation processes into a typical treatment train for surface water purification and the analysis of the treatment train operation in various process configurations constitute the promising research topics undertaken in the course of the WODTECH research project (2014-2019). The first planned publication in the membrane area discussed the research methodology (chapter in monograph E4). Papers analyzing the functioning of the water treatment train focused mainly on the NOM removal (A11, A13, E5, E7, E8, E43-E45), the role of adsorption process (A11, A13, E5, E7, E8, E43-E45) and the assessment of the DBPs formation potential (A13, E5, E45). The principal theses of the research accomplished are still to be published.

Apart from scientific research, I maintained close links with the engineering practice. Before I obtained my Ph.D., I participated in the development phase of technology for the industrial wastewater treatment plant under modernization (report J1) and in the studies related to the future modernization of the water treatment plant (reports J7, J8, J10). The subsequent application-related publications covered issues of DOC migration from plastic pipes (reports M1-M3), evaluation of the technological processes of water treatment (reports J11, J15, J17) and the analysis of cooling water system in the sewage sludge drying facility (expert analysis M4). In the period 2014-2019, I have worked for MPWiK S.A. in Wrocław, where I have been involved in many assignments providing consultancy and professional expertise (reports J20-J31, opinions M5-M8) ranging from water loss accounting, through

operational analyses for coagulation and activated carbon beds, to the treated wastewater disinfection.

In the period 1997-1998, I worked as the editor-in-chief for the quarterly *EkoTechnika*. Since 2000, I have supervised 48 diploma theses. I participated in the curriculum development of numerous teaching courses as part of the Environmental Engineering and Environmental Protection academic programs. I reviewed 24 manuscripts for publication, including 20 manuscripts in Polish and 4 in English. I have won the "*Aquarina*" Award from the year 1999 and contributed to the creation of the "Mokry Dwór" Research Station (Appendix 4, item B1).