Attachment 2b

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1. Name

Zbigniew Mucha

2. Diplomas and degrees

1992 **M.Sc. Eng. in Environmental Sciences**
Cracow University of Technology, Faculty of Sanitary and Water Engineering.
Master's thesis "The concept of tretament of leachate from a municipal waste dump for the city of Krakow at Barycz". Promoter: prof. Jerzy Kurbiel.

2004 **Ph.D in the Environmental Sciences**
Cracow University of Technology, Faculty of Environmental Engineering.
Doctoral dissertation: "Criteria and conditions for the rational use of small, highly efficient wastewater treatment plants ". Promoter: prof. Jadwiga Bernacka, reviewers: prof. Jan Suschka, prof. Renata Kocwa-Haluch, prof. Korneliusz Miksch.

2000 **Unlimited building license** for installation design in the field of water supply, sewage, heating, ventilation and gas networks, installations and equipment with technical and construction specialization for design of sewage treatment plants, License no. 97/2000

3. Employment information

2004–now **Assistant professor** at the Department of Environmental Technologies (former Department of Water and Wastewater Treatment, Water Supply and Environmental Protection Institute) of the Cracow University of Technology.

2001–2004 **Lecturer** at the Department of Water and Wastewater Treatment, Institute of Water Supply and Environmental Protection at the Cracow University of Technology.

1992–2001 **Teaching assistant** in the Department of Water and Wastewater Treatment, Institute of Sanitary Engineering and Environmental Protection of the Cracow University of Technology.

4. The achievement resulting from art. 16 sec. 2 of the Act of March 14, 2003 on academic degrees and academic title, and on degrees and title in the field of art (Journal of Laws No. 65. item 595, as amended)

4.1. Title of the research achievement

A series of related publications:

"Technological changes in small and medium wastewater treatment plants to increase nutrients removal effectiveness"

4.2. List of publications included to the application for the postdoctoral degree (Author, year of publication, titles of publication, publishing house)

Scientific publications in magazines in the database of Journal Citation Reports (JCR)

1. **Mucha Z.**, Mikosz J. (2016) A simulation study of the energy-efficient options for upgrading and retrofitting a medium-size municipal wastewater treatment plant, *Environmental Technology*, Vol. 37, Iss. 19, pp. 2516-2523.

   IF (2016): 1,751; MNiSW (2016): 25 points.; citations in Web of Science: 3

   My own contribution -70%: planning and conducting research, interpretation of results, participation in the preparation of the publication

2. **Mucha Z.**, Kurbiel-Swatek K. (2016) Analiza zastosowań reaktorów membranowych (MBR) do oczyszczania ścieków miejskich w świetle doświadczeń eksploatacyjnych i badawczych. Przemysł Chemiczny T.95, No 2, pp. 236-240

   IF (2016): 0,385; MNiSW (2016): 15 points.; citations in Web of Science: 4

   My own contribution - 80%: planning and conducting research, interpretation of results, participation in the preparation of the publication.

3. **Mucha Z.**, Kułakowski P. (2016) Turbidity measurements as a tool of monitoring and control of the SBR effluent at the wastewater treatment plant, Archives of Environmental Protection, Vol. 42, No 3, pp.33-36

   IF (2016): 0,708; MNiSW (2016): 15 points.; citations in Web of Science: 3

   My own contribution - 80%: planning and conducting research, interpretation of results, participation in the preparation of the publication.

4. **Mucha Z.**, Generowicz A., Wójcik W., Jóźwiakowski K., Baran S. (2016) Application of multi-criterial analysis to evaluation of method of utilization of sludge from small wastewater treatment plants with sustainable development of rural areas, Environmental Protection Engineering, Vol. 42, No 4, pp.97-105

   IF (2016): 0,514; MNiSW (2016): 15 points.; citations in Web of Science: 2

   My own contribution 50%: planning and conducting research, interpretation of results, participation in the preparation of the publication.

5. Mikosz J., **Mucha Z.** (2014) Weryfikacja założeń do projektu modernizacji małej oczyszczalni ścieków z uwzględnieniem nowej interpretacji wymagań prawnych. *Ochrona Środowiska*, Vol. 36, no. 1, pp. 45-49.

   IF (2014): 0,392; MNiSW (2014): 15 points.; citations in Web of Science: 12

   My own contribution 60%: planning and conducting research, interpretation of results, participation in the preparation of the publication.

Scientific publications in magazines other than those in the database of Journal Citation Reports (JCR)

6. Mikosz J., **Mucha Z.** (2017) Analiza porównawcza koncepcji modernizacji i rozbudowy oczyszczalni ścieków z uwzględnieniem czynników ekonomicznych. Gaz, Woda i Technika Sanitarna, t. 91, no 4, pp. 209-211 (MNiSW: 11 points.)

   My own contribution - 60%: planning and conducting research, interpretation of results, participation in the preparation of the publication.

7. **Mucha Z.**, Wójcik W. (2015) Investment costs of small WWTP with SBR reactors in Poland. *Ekonomia i Środowisko*, 1(52), pp. 124-130 (MNiSW: 12 points)

   My own contribution - 60%: planning and conducting research, interpretation of results, participation in the preparation of the publication.

8. **Mucha Z.** (2015) Efektywność reaktorów wielofazowych z osadem czynnym w świetle doświadczeń eksploatacyjnych. *Logistyka*, no 3, pp. 3381-3386 (MNiSW: till year 2014 10 points, from year 2015 0 points.)

9. **Mucha Z.,** Generowicz A. (2015) Metodyka wyboru wariantów rozbudowy gminnej oczyszczalni ścieków. *Logistyka*, no 3, pp. 3387-3394 (MNiSW: till year 2014 10 points, from year 2015 0 points)

   My own contribution - 80%: planning and conducting research, interpretation of results, participation in the preparation of the publication.

10. **Mucha Z.** (2014) Modernizacja oczyszczalni ścieków z wielofazowym reaktorem biologicznym w aspekcie obowiązujących wymagań. *Instal,* no 7-8, pp. 84-86 (MNiSW: 7 points)

11. **Mucha Z.**, Mikosz J. (2013) Usuwanie azotu ze ścieków w małej oczyszczalni: zastosowanie symulacji komputerowej do wyboru strategii eksploatacyjnej. *Rynek Instalacyjny*, R. 21, 5, pp. 32-35 (MNiSW: 6 points.)

    My own contribution - 70%: planning and conducting research, interpretation of results, participation in the preparation of the publication.

Other works included in the achievement

12. **Mucha Z.** (2013) Project "Upgrading and extension of wastewater treatment plant in Polana" – a chief designer of the treatment plant (in technological and installation field), Investor: Municipality of Krynica-Zdrój

My total contribution to publications included in the achievement (without 4.2.12):
- in JCR / WoS publications - 68%
- in all publications - 74%
Total IF - 3.75
Total number of MNiSW points – 121

In each of the articles included in the scientific achievement, I had a leading role in formulating the research problem, carrying out analyzes and research and developing and interpreting the results. In the sewage treatment project I was the chief designer and designer in the technology and installation branch. Copies of publications included in the series are provided in Appendix 5. The statements of co-authors of the works included in the scientific achievement, together with their individual contribution are included in Annex 6.

4.3. Discussion of the scientific goal and the results as well as their practical use

4.3.1. Introduction

Poland is a country with relatively small amounts of surface water. In addition, they are unevenly distributed across the country, and in areas with higher population density, subjected to strong anthropic pressure. A particular threat to the quality of surface water is associated with the occurrence of anthropogenic eutrophication caused by a municipal wastewater discharge[1]. Small sewage treatment plants with a size of less than 10,000 equivalent inhabitants, located in rural and suburban areas, are usually not intended to remove nutrients from wastewater.

In the Accession Treaty to the EU, Poland has undertaken a duty to implement Directive 91/271 / EEC[2] concerning urban waste water treatment. In the Treaty, the entire territory of Poland was recognized as an area sensitive to eutrophication. In order to implement the provisions of the Directive, the National Program for Municipal Wastewater Treatment (NPMWW) has been elaborated, in which alternative to the provisions of art. 5.2 of the Accession referred to in the Accession Treaty, requirements specified in art. 5.4 of the Directive. According to the position of the European Commission (EC), Poland, when implementing the Directive, should apply art. 5.2, that is, introduce higher requirements for the removal of nitrogen and phosphorus in all sewage treatment plants in agglomerations with more than 10,000 PE. The European Commission also pointed to the incorrect implementation of the provisions of art. 4 of Directive 91/271 / EEC to Polish law, in which the maximum permissible values of pollution indicators or the minimum removal rate for treated municipal and municipal sewage introduced into waters were referred to the capacity of sewage treatment plants, instead of to the agglomeration in which the sewage

[1] Chełmicki W., Woda, zasoby, degradacja, ochrona, Wydawnictwo Naukowe PWN, Warszawa 2001
[2] Dyrektywa Rady 91/271/EWG z dnia 21 maja 1991 roku dotycząca oczyszczania ścieków komunalnych (Dz. Urz. WE L 135 z 30.05.1991 r., str. 40-52, z późn. zm.; Dz. Urz. WE Polskie wydanie specjalne, rozdz. 15, t. 002, s. 26)

treatment plant is located. This means that each of the wastewater treatment plants located within the agglomeration with an equivalent number of inhabitants (PE) from 10,000 to 99999 must ensure the removal of nitrogen and phosphorus to the level of 15 g N /m^3 and 2 gP/m^3. This requires urgent and costly modernization of many small and medium wastewater treatment plants, taking into account the technology of integrated removal of biogenic compounds.

In the process of selecting a technological solution for the modernization of a sewage treatment plant, broadly understood criteria of sustainable development should be taken into account, including primarily the minimization of the negative impact of applied technologies on the environment, rational use of natural resources and social acceptance of the proposed solutions[3]. The criteria referred to wastewater treatment technologies are expressed by: efficiency of treatment, environmental impact, simplicity and ease of use, operational reliability, investment and operating costs, as well as modernity and aesthetics of the proposed solutions.

Taking into account the permissible content of nitrogen and phosphorus compounds in treated wastewater, with a slight modification to the definition of small and medium-sized treatment plants as given by Dzienis[4] and Bernacka[5] with co-workers it can be assumed that small treatment plants include facilities servicing up to 14,999PE, and medium-sized plants with facilities ranging from 15,000 to 99,999PE.

4.3.2. Scientific goal of the works

Lack of clearly defined rules and technological and environmental conditions that would be the basis for selecting solutions for modernization of small and medium-sized sewage treatment plants means that the most frequently used criterion for selecting the method of modernization is the cost of their implementation. However, chosen in this way solution is often not optimal in terms of technology, technical, operational and environmental aspects.

The main scientific goal of the monothematic series of publications intended for the habilitation procedure is the analysis and evaluation of ways to modernize small and medium wastewater treatment plants to increase the efficiency of nutrient removal, taking into account the principles of sustainable development. The main goal required to address the following auxiliary goals:

1) Identification of problems stimulating modernization in small and medium wastewater treatment plants;
2) Conducting a qualitative and quantitative characterization of incoming and treated sewage as well as technological parameters necessary for the development of input data for simulation research;

[3] Balkema, A., Weijers S., and Lambert F.,*On Methodologies for Comparison of Wastewater Treatment Systems with Respect to Sustainability.* Konferencja WIMEK "Options for Closed Water Systems. 11-13 marca, 1998, Wageningen, Holandia

[4] Dzienis L. Technologiczne podstawy modernizacji małych oczyszczalni ścieków, Monografie KIS PAN, Białystok 2005, ISBN 83-89293-95-1

[5] Bernacka. J., Pawłowska L., Krobski A. Wysoko efektywne oczyszczalnie ścieków w Polsce, IOŚ Warszawa 2001

3) Determining the possibility of using the computer simulation to verify the correctness of the choice of modernization strategies for small and medium wastewater treatment plants;
4) Determining the possibility of using the multi-criteria analysis to compare different technological solutions and choose the best variant of the modernization of the treatment plant.
5) The use of analytical and research results to improve the efficiency of nutrients removal in the process of planning modernization and expansion, and the operation of highly efficient small and medium wastewater treatment plants
6) Development and implementation of a modernization project for a small treatment plant on a technical scale .

My original contribution to the development of the scientific discipline is to identify and analyze the problems occurring during technological modernization of small and medium wastewater treatment plants and demonstrating the possibility of rational solutions using computer simulation and multi-criteria analysis. The own research is cognitive and utilitarian, and the conclusions form the basis for rational planning of modernization and expansion of small and medium-sized treatment plants with the nutrients removal .

4.3.3. Discussion of results

The subject of my analyzes and research were small and medium wastewater treatment plants with a capacity not exceeding 50,000 PE, which while designed were not intended for the removal of nutrients or were designed in a period in which milder requirements were in force. In some cases, it was necessary to introduce new technological solutions (modernization of the treatment plant) with simultaneous increase of capacity. I conducted many years of analysis and research in real conditions of sewage treatment plants, which primarily consisted of identifying technological and operational problems, and then determining the qualitative characteristics of incoming sewage and treated sewage as well as technological parameters. These data were necessary for the simulation tests.

The analysis of the operation of small treatment plants with multi-phase reactors was presented on the example of three facilities with comparable technological solutions and different pollution load , as well as operational experience from other treatment plants with multi-phase reactors [reference 4.2.8].

A number of factors affect the operation of small treatment plants with the removal of nitrogen and phosphorus compounds. Low temperature of sewage entering the sewage treatment plant due to rainwater inflow or from melting snow and increased infiltration into the sewerage system of cold groundwater leads to lower treatment efficiency, mainly nitrification, scam formation in secondary chambers and settling tanks and sludge foaming.

The inflow of accidental waters through seepage leaks leads to hydraulic overloading and periodic wash-off of the sludge from the biological reactor[6].

Too long sludge retention in the treatment system, associated with a low efficiency of its dewatering in mechanical devices (single-pass filter presses) causes higher oxygen consumption during sludge stabilization in biological reactors, which leads to hypoxic conditions preventing effective nitrification. Due to the small capacity of biological reactors, the inflow of even a small amount of highly concentrated wastewater from sewerage, supernatant, septic tank flow or rainwater can cause periodic hydraulic and / or pollution overloads, unstable unit processes, especially nitrification and periodic reduction of treatment effects.

The presented examples show that the treatment efficiency can change by factors related to the inflow of sewage, improper operation, as well as technological and technical conditions related to the processes and equipment used for wastewater treatment and sludge treatment

The required concentration of total phosphorus is easier to achieve due to supplementary chemical precipitation, but requires a good sludge separation. In my research, I mainly focused on the intensification of nitrogen removal from sewage and offered a simple example of modernization of an effluent discharge from SBR reactors in order to increase the efficiency of phosphorus removal.

Possibility of using the computer simulation to verify the modernization strategies for small and medium wastewater treatment plants

References [4.2.5 i 4.2.11]

My research on the rules for the selection of the method of modernization of small wastewater treatment plants together with the conclusions are presented in [4.2.5 and 4.2.11]. These studies were carried out in two wastewater treatment plants, where biological nitrogen removal was planned. In the first case (sewage treatment plant A), the modernization strategy focused on optimization of the existing technological system and the introduction of biological denitrification with a relatively little interference in the treatment plant infrastructure. It has been proposed to introduce anoxic conditions in a biological reactor by changing the method of aeration of activated sludge from continuous to periodic. The sludge aeration mode was determined using computer simulation techniques. In the second case (sewage treatment plant B), the modernization strategy assumed significant changes in the treatment plant infrastructure and rebuilding of the facilities, including primarily the biological reactor, in order to make the anoxic zone. Similarly like before, the technical parameters for the modernization of facilities and operating parameters of the processes were determined in simulation tests. The analysis of each of the modernization strategies presented was performed, indicating the possible benefits of their adoption and limitations of their use.

[6] Kaczor G. *Wpływ wód infiltracyjnych i przypadkowych na funkcjonowanie małych systemów kanalizacyjnych*, Zeszyt 372, ISSN 1899-3486, Wyd. Uniwersytetu Rolniczego w Krakowie, Kraków 2012

The analyzed objects are sewage treatment plants with active sludge that differ in technical solutions. None of them meets the requirements for nitrogen removal specified for agglomerations above 10,000 PE, for which the permissible concentration of total nitrogen and total phosphorus in treated wastewater is respectively 15 g N / m^3 and 2 g P / m^3.

The first of them (sewage treatment plant A) is a small multistage sewage treatment plant with a simplified activated sludge with additional chemical precipitation. The second one (sewage treatment plant B) is a treatment plant with a two-phase reactor with activated sludge and a possible additional chemical precipitation of phosphorus

Simulation tests were conducted using the GPS-X® v. 6.1 program for both treatment plants. During the research in treatment plant A, a strategy where the active sludge aeration system in the biological reactor was periodically switched on and off was analyzed. It was assumed that even such a simple exploitation strategy would clearly increase the efficiency of total nitrogen removal. Computer simulation of the treatment plant operation was carried out for 3 days. During the first day, the system operated in the current conditions with a continuous aeration and from the second day intermittent aeration in the system was introduced in the following mode: 30 min aeration followed by 30 min break.

During the simulation tests, other configurations of the intermittent operation of the activated sludge aeration system were also checked, changing the aeration time in the range of 30-60 minutes, and the duration of the break 15-60 minutes. In the sewage treatment plant B, the simulation system involved a sewage treatment plant after planned modernization and operating under the design load conditions. In this system two bi-phase biological reactors with a preliminary denitrification (anoxic and oxygen zones volume ratio equal 45% to 55%) were operated combined with one secondary clarifier. It was assumed that the introduction of the anoxic zone would allow effective denitrification and thus meet new requirements for nitrogen removal from wastewater. The basic simulations were carried out assuming a constant sewage temperature of 16°C. The detailed research objectives concerned:

- possibility of achieving the assumed technological efficiency of the treatment plant under the design operating conditions (load, quality of incoming sewage),
- feasibility and desirability of modifying design assumptions in order to achieve the required technological efficiency of the treatment plant ,
- determination of optimal values of basic operational parameters guaranteeing achievement of the modernization goals .

The results of analytical tests carried out in the treatment plant A indicated that the denitrification efficiency in the aeration chamber was about 40%, despite the fact that the entire volume of sludge was intensively aerated. This was probably due to the fact that with dissolved oxygen concentration ranging in the wide range of 1.5 - 5.5 gO_2 / m^3 and inefficient mixing of activated sludge there were local anoxic zones in the reactor. This indicated the possibility of achieving highly effective denitrification by a periodic switch off of aeration in the reactor

On the basis of the tests, it was shown that a change from a continuous to a periodic aeration introduced after the first day resulted in an increase of a denitrification rate in the

reactor from about 40 to 60-135 gN / (m^3 * d), while reducing nitrates N-NO_3 in the effluent from 50 to approx. 1.5 gN-NO_3/m^3. Denitrification also caused higher nitrification efficiency, though too low alkalinity was here the limiting factor. The alkalinity, "recovered" in the denitrification process reaches the value of ca. 170 g $CaCO_3$/m^3 and allows to intensify the nitrification process by reducing the effluent ammonium concentration from 2.2 to approx. 0.8 g N-NH_4 / m^3. The reduction in the concentration of ammonium and nitrates in the effluent has a direct effect on a significant reduction in the concentration of total nitrogen in treated wastewater from approx. 52 to approx. 2.9 g N/ m3. In addition, a reduction in the energy demand from approx. 24 to 16 kWh / d was observed after introducing periodic sludge aeration and reducing the average dissolved oxygen concentration in the bioreactor. The study shows that once the changes were introduced and with unchanged efficiency of the blowers, the oxygen concentration will range from 0.5 to 1.1 gO_2 / m^3, whereas currently the activated sludge is often "over-aerated" with an average oxygen concentration at approx. 3.5 g O_2 / m^3.

Test results from periodic aeration schemes other than the initial scheme (30 min aeration and 30 min break) indicated an increased energy demand (16-21 kWh / d) and higher concentration of total nitrogen in the effluent (3.5-14, 9 gN / m^3). It was observed that equal aeration and break times (e.g. 30 min./30min., 45min./45min.) has a positive technological effects. Therefore, it was considered that intermittent aeration with a cycle time of 30 to 45 minutes guarantees a stable system operation, with a low total nitrogen concentration in the effluent (2.9 - 3.5 gN / m^3) and reduced energy demand for aeration compared to continuous aeration.

The results of simulation tests carried out for the treatment plant B partially confirmed the design assumptions for the modernization of the sewage treatment plant. Under the assumed design conditions (defined as "scenario 1) and at sewage temperature of 16 ° C, the treatment plant did not achieve the permissible effluent concentration of total nitrogen and total phosphorus. This scenario assumed the operation of 2 blowers in a continuous manner, without controlling the oxygen concentration in the reactor, with the third blower acting as a reserve blower. It resulted in over-oxidation of the activated sludge (dissolved oxygen concentration equal to 5.5 gO_2/m^3. Although full denitrification was found in the anoxic zone, the nitrate concentration in the effluent from the oxygen zone was approx. 14.9 gN-NO_3 /m^3, which did not provide the required quality of effluent at an internal re-circulation rate of 4.5. This indicated the need to introduce the aeration system control in the reactor. Such a variant was subjected to research under scenario 2. The blower was controlled by a proportional controller (P = 0.1) depending on the oxygen concentration in the reactor oxygen zone. The optimal oxygen concentration was determined in separate series of simulations. It was found that oxygen concentration of 1.0 gO_2/m^3 was most advantageous. In this variant, the concentration of total nitrogen of 14 gN/m^3 was achieved, as well as the better removal of phosphorus, although no chemical precipitation was used

This indicates that the reactor removes phosphorus well despite the absence of an anaerobic zone. The introduction of the control of the aeration system also resulted in a lower energy demand for aeration from 163,8 to 92,6 kWh / d. With the assumed oxygen concentration in

the next stage, simulation tests were carried out to determine the required degree of internal recirculation ("scenario 3"). They show that the efficiency of nitrogen removal increases with the increasing recirculation of wastewater from the aerobic to anoxic zone, which is in line with common operational experience. The minimum recirculation to meet the effluent quality standard of 15 gN/m^3 with an appropriate safety margin is 450-500%. This is a relatively large value, although it is common at small wastewater treatment plants. With a recirculation rate of 500%, the concentration of total nitrogen in the effluent is 13.1 gN/m^3 and phosphorus 0.38 gP/m^3 (with no coagulant dosing).

Comparative analysis of modernization of small and medium wastewater treatment plants
References [4.2.1 i 4.2.6 and 4.2.10 and 4.2.2]

A comparative analysis of modernization and extension of two medium-sized municipal wastewater treatment plants with activated sludge with SBR reactors and multi-phase reactors in a flow system was presented in [4.2.1 and 4.2.6]. The plants now accept much higher pollution loads than the design ones and achieve the required treatment efficiency due to the fact that biological reactors were designed for a high sludge age. The excess sludge discharged from these facilities is currently not fully stabilized.

The proposed variants of modernization and extension in the case of sewage treatment plants with SBR reactors differ in sludge stabilization process solution [publication 4.2.6]. The first variant uses separate aerobic stabilization and in the second one anaerobic stabilization with biogas utilization. Based on the analytical tests and the computer simulations, I analyzed the investment and operating costs of the modernization options and their environmental impacts in relation to the greenhouse gas emissions. The results of the analysis showed that the more cost-effective variant with anaerobic stabilization of sludge has lower operating costs, due to a possible energy recovery from biogas, as well as lower greenhouse gas emissions by 59 t CO_2eq^{r-1}. This variant takes into account the cogeneration of electricity from biogas in the CHP system, which should cover at least 30% of the total electricity demand.

In the treatment plant with multi-phase reactors [publication 4.2.1] modernization of the existing combined reactor with a secondary settling tank involved construction of a separate settler which will increase the reactor capacity and as a variant installation of microfiltration membrane modules in the existing reactor. In both cases, anaerobic digestion of sewage sludge was planned.

Simulation tests were conducted using the GPS-X® v. 6.1 program. The models of the treated wastewater treatment plant included both sewage treatment and sludge treatment processes with energy consumption and production data[7]. In the first stage, I developed the assumptions for constructing the model of an existing sewage treatment plant using exploitation data (model 0). In the second stage, the model became the basis for the development of models reflecting two modernization options considered: with a separate

[7] Langergraber G, Rieger L, Winkler S, Alex J, Wiese J, Owerdieck C, Ahnert M, Simon J, Maurer M (2004) *A guideline for simulation studies of wastewater treatment plants*. Water Sci Technol 50(7):131-138

secondary settling tank (model 1) and with membrane filtration (model 2). In the third step, simulations were carried out in which the capacity of sewage treatment plants (model 0, model 1 and model 2) was analyzed in four different operational scenarios (A-D), which differed in process temperature and pollution load of the treatment plant. For each scenario, quality of effluent and energy balance were determined. The load scenarios included: (1) the actual average load; and (2) load increased by 50% compared to (1). The energy balance included energy consumed for: pumping and recirculation of sewage, mixing and aeration of sludge, concentration and dewatering of the sludge and heating the sludge during anaerobic digestion.

The results of simulation tests should be considered in the context of two main objectives of the planned modernization of the plant, i.e.: guarantee of the required effluent quality and better overall energy efficiency of the treatment plant. The simulation results showed that in both variants of modernization the required process efficiency will be ensured even at low temperature and with a 50% load increase. In such a situation, the energy balance of the sewage treatment plant will be the main criterion for choosing the best modernization option.

Energy consumption in a sewage treatment plant without modernization range from 0.674 to 0.893 kWh / m^3 depending on the load

In the variant with the secondary clarifier, less energy is required for aeration compared to the existing installation, and moreover, biogas produced in separate digesters can be used to generate heat or electricity that further improves the energy balance. Energy consumption indicators decrease along with the increase in the amount of incoming sewage and it varies from 0.033 to 0.540 kWh/m^3 of treated wastewater. In the variant with membranes, intensive aeration of membrane modules increases the energy demand by about 20% compared to the first variant. In addition, due to a better mineralization of excess sludge, the organic mass stream in the inflow to the digesters is smaller and the total amount of produced methane is reduced. As a result, the overall energy balance is negative, although it improves with an increasing load.

Membrane filtration should be considered as an option for modernization, where space saving and stringent wastewater quality standards are key issues. Membrane reactors are also useful in the case of treatment plants with seasonal changes in pollution loads [publication 4.2.2]. However, in many cases, similar effects can be obtained by optimizing the existing sewage treatment infrastructure. The research conducted in the medium-sized urban sewage treatment plant showed that technological and technical optimization of the biological reactor and construction of a new secondary clarifier allowed to increase the capacity of the sewage treatment plant without implementing membrane filtration. An important advantage of this approach is a better energy balance of the plant. An optimized wastewater treatment line with a new sludge treatment , which uses excess sludge digestion and biogas recovery, provides a positive energy balance, bringing the plant closer to energy self-sufficiency. In the case when membranes are used for separating activated sludge from wastewater, positive energy balance values are only achieved at high loads.

The scope of modernization of the sewage treatment plant with a multi-phase biological reactor together with cost analysis was developed in two variants and presented in [4.2.10]. Analysis of a composition of the incoming sewage and the final effluents as well as technological calculations have shown that there are possibilities to increase the efficiency of nitrogen removal by modification of the biological reactor associated with increasing the capacity of the anoxic chamber, upgrading of aeration and wastewater and sludge recirculation. I proposed two variants for a phosphorus removal from wastewater: an excess biological process and iron salt dosing (PIX).

The technological and economic analysis has shown that the use of a two-phase reactor with activated sludge and phosphorus precipitation was better option of modernization, despite the fact that the costs are more than twice as high as in the variant with excess biological removal. It is mainly connected with higher investment costs of anaerobic digester with a stirrer, and also with the sewage characteristic, where a relatively low concentration of phosphorus does not require high doses of PIX .

Unconventional way of modernization of a small sewage treatment plant with nitrogen and phosphorus removal was proposed in a facility with the SBR [publication 4.2.3]

The effluent discharge is carried out using a floating decanter. The first wave of effluent containing activated sludge suspension is directed to the wastewater reservoir. The discharge time of the first portion of the effluent is set during a start-up phase and can then be adjusted by setting the time of opening of the automatic valve on the pipeline. In the case of emergency when large amount of activated sludge in the effluent is observed, the required total phosphorus concentration in the effluent may not be met.

The aim of the study was to determine the relationship between the on-line turbidity measurements in the effluent and other pollutants , which allowed implementation of the first wastewater discharge control system using a decanter. In the design of the plant, turbidity measurements were conducted on the discharge pipeline with a turbidimeter Turbimax CUS51D from Endress + Hauser. They were never intended to be used for process control, but only for general monitoring of wastewater quality.

In my research I found a very high correlation between suspended solids concentration and turbidity in the effluent, which allowed to control the discharge of the first portion of the effluent depending on its turbidity, and not on the SBR time mode (opening of the gate valve for a first discharge).

Applicability of a multi-criteria analysis to compare different technological solutions and choose the best variant of the treatment plant modernization and methods of sludge dewatering and management

References [A.2.9, A.2.4 and 4.2.7]

The decision regarding the application of the modernization solution for sewage treatment plants requires analysis of a number of technological and environmental factors, local conditions and should be preceded by a careful economic analysis.

I used the methods of multi-criteria analysis to select the optimal variant of expansion and modernization of the group sewage treatment plant, based on the case study of a municipal sewage treatment plant, which had to improve its nutrients removal in connection with the established agglomeration above 10,000 PE [publication 4.2.9], and methods for sludge dewatering and management [publication 4.2.4].

Multi-criteria analysis is a mathematical method that allows you to choose the best solution from among many options or strategies described. The condition for finding a solution is the adoption of a set of indicators (criteria) evaluating particular variants. The decision problems presented for the solution are discrete decision problems, the evaluation of which requires many partial assessment indicators. In the case of discrete problems, the final product is a finite set of numbers, which are the results of the evaluation of the developed variants against selected criteria. Each decision task must be described through the development of decision-making variants and the development of evaluation criteria and methods for their estimation.

The mathematical record of the formulated decision-making task, described by the developed decision-making variants and the estimated values of criteria for evaluating variants, is the so-called a decision matrix, i.e. a table of numbers, in which the evaluation criteria are referred to as these numbers being the consequences of the implementation of individual variants, measured in terms adopted as measures of assessment.

A proposed modernization of the treatment plant to meet the requirements of nitrogen and phosphorus removal, in connection with the new agglomeration above 10,000PE is presented in [4.2.9]. In the first option, I proposed a solution using a SBR (Sequencing Batch Reactor) technology well-proven in the rural areas, and in the second one membrane reactors with ultrafiltration membranes installed in the existing activated sludge reactors. In the first option, the construction of new biological reactors with a blower station in additional area is required. The existing facilities will be used as retention tanks and the aerobic sludge digester. In the second variant, the construction of a new sludge digester is required in the existing treatment plant.

For dewatering and management of stabilized sludge produced at a small sewage treatment plant with SBR reactors, I proposed natural sludge treatment methods [publication 4.2.4]:

For the objective and the widest evaluation of the task, it is best if the criteria take into account different aspects of the assessed option, although they may present different, often conflicting goals, e.g. we are looking for the cheapest solution, while the most reliable one. Therefore, variants should be described as broadly as possible and measured, while selection is a compromise choice, depending on the importance of individual criteria[8]. Technological, economic and environmental criteria were taken into account in the technological variants that were analyzed. When defining specific criteria, an individual approach to each decision problem is necessary. Detailed criteria of the assessment are presented in publications [4.2.9 and 4.2.4]. To calculate investment costs, I have adopted unit cost indices for the construction of a sewage treatment plant with SBR reactors based on data developed

[8] Brechet T., Tulkens H., *Beyond BAT: Selecting optimal combinations of available techniques, with an example from the limestone industry*. Journal of Environmental Management 90 (2009), 1790–1801.

statistically from several dozen treatment plants included in [4.2.7], and a sewage treatment plant with MBR reactors based on cost estimates of companies offering technological solutions.

All criteria were priced on a point scale, in addition to economic criteria, where investment and operating costs were reported in zlotys.

For the calculation of variant modernization of the treatment plant, I used two methods of multi-criteria analysis: Bordas and weighted sums, and for calculating the method of dewatering and sludge management - the method of compromise programming[9].

The Bordy calculations showed that both solutions, both the SBR-treated sewage treatment plant and the membrane plant with a membrane reactor, are equivalent and equally good. This method did not give an unambiguous answer, which solution should be applied, therefore, other criteria should be additionally taken into account or a different, more accurate method of choice should be used.

The weighted sum method, on the other hand, gives more complex results due to the possibility of giving weight to individual evaluation criteria. In the assumptions for calculations different weights were adopted and different results were obtained depending on the adopted weights, depending on the preferences of the decision maker. The decision maker can accept certain restrictions in the choice of strategy.

The results of calculations with the weighted sums method showed that for the 16 calculation cases 9 times as the most advantageous technological solution, a sewage treatment plant with SBR was selected. In six cases, the solution with membrane reactors was chosen as the most advantageous technological solution. In one case, when the criterion of "modern solution" is twice as important as the others, both solutions are equivalent, as in the Bordy method. In addition, in 10 computational cases, both technological solutions are located very close to each other. So you can treat them as equally good.

Summing up the results for the method of dewatering and sludge management from a small sewage treatment plant, it can be concluded that in 48 computational cases, assuming different weights of individual criteria, in most cases a filter press with lime hygienization was selected as the most beneficial dewatering technology ; roofed shelter with sludge disposal to the composting plant was the least advantageous one.

Design achievements [4.2.12]

One of the elements of the achievement presented in the application is a project for the modernization of a small wastewater treatment plant to increase the efficiency of nutrient removal. It was chosen as one of many projects I carried out for small, highly efficient wastewater treatment plants implemented in the technical scale [app. 3, B.2]. The premise

[9] Aragonés-Beltrána P, Mendoza-Rocab J A., Bes-Piáa A et al., *Application of multi-criteria decision analysis to jar-test results for chemicals selection in the physical–chemical treatment of textile wastewater.* Journal of Hazardous Materials 164 (2009), 288-295.

to choose was the fact that this project was verified using computer simulation and presented in the publication included in the scientific achievement [4.2.5].

Wastewater treatment plant in Polana near Krynica-Zdrój was designed and built for a capacity of 230m^3/d and PE = 2,300 . It is a mechanical-biological treatment plant with two-phase activated sludge reactor and a possible chemical precipitation of phosphorus. A fine screen with a 3 mm clearance was used for mechanical treatment. All technological devices, except for the measuring chamber, were located in one building. In the biological stage, there are two treatment lines with activated sludge with the anoxic (denitrification) and oxygen (nitrification) zones and secondary clarifiers with vertical flow (so-called pocket settling tanks). The anoxic zones were equipped with horizontal axis agitators while oxygen zones with tubular diffusers. Recirculation of sewage along with the sludge took place from the separation zone placed in the oxygen zone to the anoxic zone.

The chemical precipitation of phosphorus was carried out with iron (III) sulfate added to the aerobic zone before settling tanks. The sludge treatment involved aerobic stabilization in the reactor, sludge thickening in the gravity thickener (located in the anoxic zone) and storing in the tank. The thickened and stabilized sludge was transported in a liquid state to a larger treatment plant for its dewatering. The technological scheme of the sewage treatment plant before modernization is shown in Figure 3 in Annex 5.

The project was designed to meet the permissible values of BOD_5 = 25 gO_2 / m^3, COD = 125 gO2 / m3 and TS = 35 g / m3 in treated wastewater. This plant, despite the use of an activated sludge chamber with nitrification and denitrification, did not meet the requirements for nitrogen removal specified for agglomerations of more than 10,000 PE and required modernization.

Modernization of the treatment plant, in accordance with the requirements of the Investor, was provided for the same capacity as in the original design, and with the largest possible use of existing facilities and technological equipment.

My project achievement consisted in the development of technological assumptions, description and selection of equipment, drawings and coordination of design work of other professionals (constructor and electrician).

Technological changes proposed during modernization comprised :

1) increasing the active capacity of biological reactors by removing pocket settlers and thickeners from inside the reactors,
2) increasing the volume of anoxic chambers to 47% from the existing 25% of the total reactor capacity by using an alternating aeration zone,
3) construction of a secondary clarifier with a diameter of 7m outside the technological building with a scraper of floating parts (serving both reactors) with a recirculation pumping station,
4) adaptation of the sludge tank with a capacity of 200m3 to a separate aerobic digester (WKS).
5) using PAX (polyaluminum) dosing station for elimination of filamentous bacteria
6) increasing the efficiency of the iron sulphate dosage station (PIX)

Modernization works in the sewage treatment plant were made in accordance with the project, and since 2013, after the technological start-up, the plant meets the required efficiency in accordance with the water permit.
A construction project (without technical design and electrical design) consisting of a descriptive and drawing part is presented in Annex 5.

Summary

The need to remove nitrogen and phosphorus at sewage treatment plants located within the agglomerations with PE greater than 10,000 requires use of biological nitrification and denitrification processes to remove nitrogen and a biological excess removal of phosphorus supported by chemical precipitation. Modernization of these facilities will be based on process changes that can proceed through operational or technical/process modifications that enable a nutrient removal as well as a complete change of treatment plant and a swich over to new technology, usually to a multi-phase activated sludge system. The final decision on the modernization method, due to the significant costs of adopting stricter quality requirements, should be based on a reliable comparative technological and economic analysis [publications 4.2.6 and 4.2.10] taking into account environmental aspects [4.2.9]. An important factor in modernization, especially for older sewage treatment plants, is reduction of energy consumption in both sewage treatment and sludge treatment processes [publications 4.2.1, 4.2.6].

The results of my research have shown that in many cases it is possible to achieve satisfactory results in the nutrients removal without making significant changes to the infrastructure of small wastewater treatment plants, and only by optimizing the operational strategy [publications 4.2.11, 4.2.3]. The results also show that if it is necessary to reconstruct the treatment plant infrastructure, computer simulation may be a useful tool for verifying the scope of the necessary modernization [publications 4.2.1, 4.2.5].

The performed calculations confirmed the usefulness of the application of multi-criteria analysis to the assessment and selection of the variant of extension and modernization of the municipal sewage treatment plant [publication 4.2.9], and methods of sludge dewatering and management [publication 4.2.4], in aspect of various accepted and estimated evaluation criteria. Using the multicriteria analysis to compare technological and technical variants, an additional aspect allowing comparison is adoption by the decision maker of the hierarchy of validity of criteria, which allows to distinguish the criteria for which we want to pay special attention.

4.3.4. Possible application of results

The results of research, design and implementation works presented by me can be directly applied in the design and operation practice of wastewater treatment plants and as a basis for further research in this area. The research results should contribute to the rational planning of modernization and expansion of small and medium-sized sewage treatment plants, which will enable the use of appropriate technological solutions ensuring

the required cleaning efficiency, taking into account economic and environmental aspects. To determine the type and scope of necessary modernization activities, computer simulation can be used, thanks to which it is possible to optimize the process.

5. Other scientific achievements

5.1. Before PhD

In 1992, I graduated from the Faculty of Sanitary and Water Engineering at the Cracow University of Technology in Kraków, specializing in Water Supply and Sewage and Waste Utilization, with a master's degree in engineering. My diploma thesis were: "The concept of leachate treatment from municipal waste dump for the city of Krakow in Barycz. The supervisor of the work was prof. Jerzy Kurbiel. As part of my Master's thesis, I carried out technological research on various treatment systems for landfill leachate. The effect of research were the conference papers delivered by me (Annex 4, B.16, B.17). In 1994 at the Higher School of Engineering in Zielona Góra I received an award for the best paper (assignment 4, B.17) delivered at the 16th International Scientific Symposium of Students and Young Workers of Science in the field of sanitary engineering.

Since starting work at the Cracow University of Technology's Water and Wastewater Treatment Plant in 1992, my scientific interests have always focused on issues related to local sewage disposal and treatment systems as well as operation of small wastewater treatment plants.

From the beginning of my professional career, I tried to participate in the scientific and publishing activity of the Institute, which resulted in 16 publications before my doctoral thesis. These were mainly national and international conference publications, as well as scientific and popular science journals (Annex 3, B5.34 to B5.39 and B.13.14 to B.12.23). I have also done many works commissioned from industry and local government units (Annex 3, B.2, B.6 and Annex 4, M). These were design and conceptual works, as well as opinions and expert opinions related to development, modernization and operation of sewage treatment plants and sewage systems. Since 1993, I have participated in many technological start-ups of the sewage treatment plant as a start-up manager and / or a process engineer (Annex 4, Q7) and I conducted maintenance training for the treatment plant staff. I also carried out many of technological supervision in the sewage treatment plants, e.g.: Stanisławice, "Szarów" in Targowisko, and Kłaj.

In 1996, in a team with dr Jerzy Banas and dr Wieslawa Styka we have developed a series of SBR CYKLOB sewage treatment plants (Annex 4, M) and implemented a highly efficient sewage treatment technology with activated sludge in a sequential process in several facilities, including Magnuszew, Mikołajki, Rogów.

Since 2000 I have a design license (no. 97/2000, MAP / IS / 1442/01) so I can design without any limitations installations of water supply, sewage, heating, ventilation and gas networks, technical and construction specialization for design in the field of sewage treatment plants. I am the author or co-author of dozens of implemented sewage treatment

projects with different capacity (Annex 3, B2), as well as technological concepts for modernization and extension of sewage treatment plants (Annex 4, M).

In the pre-doctoral period, I also took part in international cooperation. In 1996, I took a short-term internship abroad at the Royal Institute of Technology in Stockholm, and in 1997 at England Polytechnic University in Cambridge (UK) under the TEMPUS-PHARE JEP program. In 1996, I participated in a two-week intensive German language course for academic teachers at Friedrich Schiller Universitaet Jena.

In 2002, I obtained a supervisory grant from the KBN for the implementation of the project entitled: "Criteria and conditions for the rational use of small, highly efficient wastewater treatment plants (MWOŚ)". The grant manager was my then academic supervisor Prof. Jerzy Kurbiel, then Prof. Jadwiga Bernacka. The result of research on the above. the subject, in addition to the PhD thesis defended in 2004, were the conference papers I gave (Annexes 4, B.11, B12), and publications (Annex 3, B.23, B.24, B.25).

5.2. After PhD

After the defense of my doctoral dissertation, my first scientific works were related to the subject of wastewater treatment and sludge treatment in small wastewater treatment plants. I have pursued and continued my research interests and activities in the following research areas:

1) The use of decision analysis for the selection of the most advantageous method of removing and treating wastewater from small settlement units,

2) The economic aspects of wastewater treatment,

3) Application of natural methods of treatment of small amounts of wastewater,

4) The use of membrane techniques in wastewater treatment

I carried out research work as a contractor as part of work financed from budgetary funds for the statutory works of the Cracow University of Technology. These were the following research projects: "Improvement of analytical, technological and statistical methods meeting new standards in wastewater quality at modernized wastewater treatment plants", Analytical, technological and statistical research in the field of sewage and waste technology (including sewage sludge) in relation to issues included in plans national sewage and waste management "in 2012-2014 and" Unit processes and technologies in engineering and environmental protection "in 2015-2017 [Annex 3, B.10.1 - B.10.6].

I used multi-criteria analysis to select a method for removing and treating small volumes of sewage in rural and suburban areas [Annex no. 3, B.1.3, B.5.3, B.5.6, B.5.7, B.5.15, B.5.16, B.5.18]. To choose the optimal solution, I used the sustainability criteria taking into account technical, economic, environmental and social aspects, and for calculations one of the methods of decision analysis: compromise programming or hierarchical AHP (Analytical Hierarchy Process). These methods are an environmental management tool. The proposed methods have confirmed their suitability for solving multi-criteria decision problems and can

be used to select the best solution at the stage of planning and designing wastewater removal and treatment systems in small settlement units.

Minimizing the operating costs of a sewage treatment plant is one of the most important issues related to the treatment of sewage in large and small facilities, and investment costs are still an important criterion in the selection of a technological solution. Issues related to the energy consumption of small wastewater treatment plants were presented in the publication [annex 3, B.12], and the structure of energy consumption in the publication [annex no. 3, B.8]. The research results indicate that the average unit energy consumption indicators in small wastewater treatment plants are very high and energy optimization is a necessary element.

I conducted research on natural methods of treatment of a small amount of domestic wastewater in facilities using wetlands, aerated ponds and Lemna ponds as well as gravel filters. These purifiers provide full biological purification and are characterized by simplicity of solutions and ease of use as well as operational reliability, allowing to minimize technical supervision during operation and operating costs.

Studies of small hydrofitic treatment plants in a one-stage system have shown that these objects, during many years of operation, achieved the required treatment efficiency and reliability of operation in relation to the basic pollution indicators [Annex. 3, B.1.1, B1.2, B.5.1, B.5.13].

The results of a comparative analysis of three variants of modernization and extension of a small wastewater treatment plant with aerated ponds and polishing ponds of the Lemna type were presented in the publication [annex no. 3, B.5.1]. The expansion options assumed increasing the capacity of the treatment plant and maintaining the existing biological ponds. For each of the variants, I conducted an efficiency analysis supported by simulation research. The results showed that under specific local conditions properly applied natural methods can be an effective supplement to treatment systems in small wastewater treatment plants.

The assessment of the work of a small treatment plant with a gravel bed after its modernization, i.e. replacement of the fill and the increase of the bed surface as well as use of a filter at the settling tank discharge to stop the solids I presented in the publication [Annex 3, B.5.13]. At the request of the SS Norbertines Monastery in Imbramowice I took over supervision of the small sewage treatment plant, which was modernized according to my guidelines (Annex 3, B2). For several years, the study of treatment process efficiency was carried out by the Cracow University of Technology. The results of the study as well as the scope of modernization were published in the journal from the B list of the Ministry of Science and Higher Education [annex no. 3, B5.13].

The research on the application of membrane techniques for municipal wastewater treatment was carried out with the use of Microdyn Nadir submerged membrane modules BIO-CEL® made of UP 150 membrane membranes with a pore size of 0.05 µm (150kDa) made of hydrophilic polyethylene sulphone (PES). . 3, B.5.10].

The test results confirm the possibility of using membrane reactors for municipal wastewater treatment if only a highly effective mechanical treatment with removal of screenings, sand, fats and hair and fibers is used and what is particularly important in smaller wastewater treatment plants a professional service for operation of technologically advanced solutions is available .

Plants with membrane reactors can be an alternative to small and medium-sized conventional treatment plants with activated sludge. These plants are insensitive to technological disturbances associated with sludge bulking and the membrane reactor effluent is of high quality. Such plants can also be used in the case of expansion and modernization of a sewage treatment plant with activated sludge when there is no land for new technological facilities.

In addition to the research areas outlined above, my interests also included other topics that did not fit directly into the mainstream of my scientific and research activity. These included, among others:

- groundwater treatment,
- hazards to the water environment caused by sewage and waste from the industrial tank,
- reducing the odor nuisance of the pressure sewage system.

The results from these studies were presented in a number of articles in journals from the JCR list (Annex 3, B.1.5), from the list of Ministry of Science and Higher Education [attached. 3, B.5.5; B.5.6, B.5.15].].

Cooperation with industry

The research issues presented above are also the topics of my work carried out as part of cooperation with industry and work for local government units. I am the author or co-author of many completed projects and technological concepts of small and medium wastewater treatment plants [Annex 3, B.2, Annex 4, M]. Many of these facilities (Dobra, Szczyrzyc, Ujanowice, Stryszów, Biertowice, Sromowce Niżne, Skała, Limanowa, Wołowice) were the subject of research [Annex] 3, A.2.3, A.2.6, A.2.8, A.2.10, B.5.2].

My project "Modernization of sewage treatment plant - extension of the sludge dewatering plant at 35c Kasprowicza St. at Zakopane "[est. 3, B.2] was submitted by the Investor and participated in the "Modernization of the Year 2008" competition.

In the years 2003-2007 I was a technology expert at the Ove Arup & Partners Contract Engineer's Office in the project entitled "Management and supervision over the construction of the Płaszów II sewage treatment plant in Krakow". In 2009, the team of the Contract Engineer, with me as a member, received the award in the competition under the patronage of the Ministry of Regional Development - 3rd edition of 2007. "EKO - INVESTMENT LEADER" in the Contract Engineer category for Ove Arup & Partners Ltd Branch in Poland for the implementation of the project "2000PL / 16P / PE / 012 Modernization and extension of the Płaszów II sewage treatment plant in Krakow" (Annex 4, D.4),.

In 2012-2013 I was a consultant (expert) at Marseplast Sp. z o.o. Niepołomice for the technology of plastic application for the production of household sewage treatment plants.

On the basis of my technological concept, a prototype was made and technological research was carried out on the household sewage treatment plant (Annex 3, B6.5, B6.7).

In the years 2011-2013 I was in charge of the author's supervision in the project "Construction of wastewater treatment plant in Wołowice Stage I, and extension of the wastewater treatment plant in Wołowice Stage II". It is a treatment plant with SBR reactors in a steel structure with high requirements for nutrient removal. In the wastewater treatment plant I also conducted research [4.2.3].

I have worked with many companies dealing with wastewater management, including Huber Technology, Marseplast Niepołomice, Schwander Polska, Ove Arup & Partners Limited, Sotralentz, DDS Phoenix and many companies and local government units operating sewage treatment plants [Annex. 3, B.2, appendix 4, M].

Currently, I am the manager of the project "Research and development works at the Chełmiec MBR sewage treatment plant" carried out in cooperation with the entrepreneur [app. 4, F]. The research is aimed at the technological and economic optimization of membrane reactors (MBR) for the treatment of municipal wastewater with the possibility of reusing the effluent.

The opportunity to participate in all stages of the investment process related to the implementation (modernization) of many small and medium-sized sewage treatment plants from technological concepts and design through author's supervision over the construction of facilities and equipment assembly as well as start-up and operation, enabled to gain a lot of experience used in research and teaching activity.

6. Summary of achievements

6.1. **Research activity** (including references presented in sec. 4)

Type of achievement		Before PhD	After PhD	Total
Total number of publications		16	53(54)*	69(70)*
Papers from the JCR list		-	10 (11)*	10 (11)*
Papers in magazines other then the JCR list		5	25	30
Author of a chapter in a monography		1	6	7
Publications in the conference proceedings (Polish and foreign)		10	12	22
Active participation in the Polish and international conferences		6	11	17
Completed original design, construction achievements		14	20	34
Patents		-	1	1
Participation in international research projects		2	6	8
Collective studies, documentation of research works		14	7	21
Expertise or other studies prepared for the order of public authorities, local governments or entrepreneurs		59	130	189
Reviewing articles		-	6	6
Supervision of PhD students		-	1	1
Basic bibliographic indicators				
Total IF as in Web of Science *(according to the publishing year)*		-	**11,937 (13.057)***	**11,937 (13.057)***
Number of citations (without self-citations) (as of 20/04/2019)	**Web of Science**	-	**78 (71)**	**78 (71)**
	SCOPUS	-	83 (75)	83 (75)
	Google scholar	-	200	200
Hirsch Index (as of 20/04/2019)	**Web of Science**	-	**5**	**5**
	SCOPUS	-	5	5
	Google scholar	-	8	8
Total points MNiSW		**13**	**392**	**405**

**) including one publication accepted for publication in the journal AEP with IF = 1.12*

6.2. Teaching and propagation

My teching and popularizing activities are closely related to the scientific and research activities. I have been teaching since 1992. Initially, they were design and laboratory exercises in the subject of "Wastewater Treatment". During this period, I also carried out the projects on "Water Treatment" and "Wastewater Treatment".

After obtaining the doctoral degree, I conducted and continue lecturing at full-time and part-time studies in:

- Operation of water treatment and wastewater treatment systems (Environmental Engineering, module manager),
- Local water and wastewater treatment systems (Environmental Engineering, module manager),
- Constructions for water and wastewater treatment (Water and Sanitary Construction until 2012)

systemy oczyszczania wody i ścieków (Inżynieria Środowiska, kierownik modułu),

- Designing of buildings and devices for water and wastewater treatment (Water and Sanitary Construction until 2011, module manager),
- Natural methods of wastewater treatment (Environmental Protection until 2018, module manager)
- Law in environmental protection and municipal engineering (Renewable energy sources from 2018, module manager)
- Conditions of the investment process (Environmental Engineering from 2018, module manager)

In addition, I taught project classes on "Treatment of sewage sludge" and on "Water and sewage infrastructure in local and over local planning".

For many years I have been teaching classes on wastewater treatment and sludge processing at the postgraduate studies of the Cracow University of Technology "Water supply, disposal and disposal of wastewater and methods for analytical water and wastewater quality assessment" and at the Inter-faculty Postgraduate Studies - "Environmental Protection in urban areas", on "Wastewater treatment in small wastewater treatment plants", "Mechanical wastewater treatment - processes, devices".

In the didactic classes with students, I use the experience acquired during my research and design work.

I was a supervisor of 81 master's and engineer's theses (8 of them were awarded) and 10 post-graduate works. The subject of my diploma and postgraduate theses is strictly related to the scope of my interest. These were design, research and study works.

For teaching achievements, I received the first-degree team award of the Rector of the Cracow University of Technology (2009) and the Honorary Badge of the Cracow University of Technology (2011) for the didactic and organizational work.

In 2012, I was selected by the students as the Best Lecturer of the Faculty of Environmental Engineering in the field of environmental engineering.

I attach great importance to the training of designers and operators of sewage treatment plants. In 2011-2012 I conducted a 3-day training (three editions) in operation of small wastewater treatment plants as part of the project "Cracow University of Technology for SMEs - trainings improving the competences of cadres of modern economy in the sectors of engineering and environmental protection and construction". Since 2015, every year I conduct a two-day training for employees of the "Górna Raba" company in the field of sewage treatment plant operation. For many years, as part of the performed start-ups of the sewage treatment plant, I have been conducting training sessions for the sewage treatment plant staff.

6.3. Organizational work, research cooperation

After my doctoral degree, my organizational activity focused on the work at the university and in the department. In 2004, I was a member of the Faculty Recruitment Commission, and in the years 2006-2007 I participated in the work of the Institute's Defense Commission as secretary.

In 2010, I took part in the promotion of the Faculty of Environmental Engineering as part of the "Open Days of the Cracow University of Technology" and in 2011 as part of the "Days of Water".

In 2004, I prepared and delivered an inaugural lecture for part-time students, and in the years 2005-2012 I participated in the presentations of the specialty "Sanitary Engineering" and "Water and Sanitary Construction".

In 2011-2015, I took part in a project implemented by the Cracow University of Technology as part of the Human Capital Operational Program entitled "An increase in the number of graduates of the Faculty of Environmental Engineering at the Cracow University of Technology who are able to use knowledge in creating development that meets environmental requirements" as a manager for compensatory classes.

In 2017, I took care of student internships. I am currently a member of the Faculty Commission for the Quality of Education.

As part of cooperation with foreign research centers in 2005-2009, I participated in the international cooperation program between the Cracow University of Technology, the Royal Institute of Technology (Sweden) and the National University "Lviv Polytechnic" (Ukraine) under the VISBY program "Research and application of new technologies" in wastewater treatment and municipal disposal in Ukraine, Sweden and Poland ". As a result of this cooperation, two chapters in foreign monographs were published [Annex 3, B.5.15, B.5.19].

As part of scientific cooperation with scientists from the University of Life Sciences in Lublin, Gdańsk University of Technology, SGGW in Warsaw and the University of Agriculture in Krakow, publications from the JCR list were published [Annex. 3, B.1.1, B.1.2, B.1.7, B.1.8].

Zbigniew Mucha